MARCH, 1957

DENTAL CLINICS *of* NORTH AMERICA

SYMPOSIA ON

I. New Developments in Operative Dentistry

DREXELL A. BOYD, D.D.S.

II. Differential Diagnosis of Prosthodontic Needs

RAYMOND J. NAGLE, D.M.D.

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Contributors

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L. Rush Bailey, D.D.S. Chairman, and Professor of Prosthetic Dentistry and Consultant in Crown and Bridge, Indiana University School of Dentistry.

Ralph H. Boos, D.D.S. Minneapolis, Minnesota.

Drexell A. Boyd, D.D.S. Chairman, and Professor of Operative Dentistry, Indiana University School of Dentistry.

David H. Coelho, D.D.S., F.A.C.D. Professor and Chairman, Fixed Partial Prosthesis, New York University College of Dentistry.

Herbert D. Coy, D.D.S. Professor of Operative Dentistry and Director of the Dental Clinic, Medical College of Virginia School of Dentistry.

Muller M. DeVan, D.D.S., F.A.C.D. Professor of Clinical Prosthetic Dentistry, Chairman of the Department of Prosthetic Dentistry, and Supervisor of Post-graduate Courses in Prosthetics, University of Pennsylvania School of Dentistry. President of the Academy of Denture Prosthetics. Vice-President of the American Board of Prosthodontics. Consultant at U. S. Naval Hospital, Philadelphia; Fort Dix and Valley Forge Army Hospitals; Veterans Hospital, Wilmington, Delaware.

Robert E. Doerr, D.D.S., M.S. Assistant Professor of Dentistry, University of Michigan School of Dentistry.

Roland D. Fisher, D.D.S., F.A.C.D., F.I.C.D. Teacher and Demonstrator of the subject "Dentogenics," Extension Division of the University of California School of Dentistry. Consultant in Prosthodontics, Veterans Administration, Los Angeles, California.

Arthur B. Gabel, D.D.S., M.A. Edwin T. Darby Professor of Operative Dentistry and Chairman of Department, University of Pennsylvania School of Dentistry.

Harry J. Healey, D.D.S., F.A.C.D. Professor of Operative Dentistry and Chairman, Division of Endodontics, Indiana University School of Dentistry.

Fredrick A. Hohlt, D.D.S. Assistant Professor of Operative Dentistry, Indiana University School of Dentistry.

Joseph S. Landa, D.D.S., F.A.C.D. Professor of Denture Prosthesis (Postgraduate), New York University College of Dentistry. Attending Prosthodontist, Polyclinic Hospital and Medical School; Associate Attending Prosthodontist, Beth Israel Hospital. Fulbright Professor in Prosthodontics at Tokyo Medical and Dental University, Tokyo, Japan, 1955–1956.

William Lefkowitz, D.D.S. Professor of Dentistry, The Ohio State University College of Dentistry.

Arvin W. Mann, D.D.S., F.I.C.D. Research Consultant, Clinical Center, National Institutes of Health (U. S. Public Health Service), Bethesda, Maryland.

R. A. McEwen, D.D.S., F.A.C.D. Atlanta, Georgia. Formerly Professor and Chairman, Fixed Prosthesis, Atlanta-Southern Dental College, Emory University.

John H. Mosteller, D.D.S., F.I.C.D. Mobile, Alabama.

Raymond J. Nagle, D.M.D. Dean and Professor, Denture Prosthesis, New York University College of Dentistry.

S. Howard Payne, D.D.S., F.A.C.D., F.A.D.P. Assistant Dean and Professor of Prosthodontics, University of Buffalo School of Dentistry. Consultant in Prosthodontics, Meyer Memorial Hospital, Buffalo Children's Hospital and Regional Veterans Administration Hospital.

HARRY H. POSTLE, D.D.S. Assistant Professor of Dentistry, The Ohio State University College of Dentistry.

JEROME M. SCHWEITZER, D.D.S., F.A.C.D., F.I.C.D. Special Lecturer in Prosthodontics, University of Pennsylvania School of Medicine. Visiting Dentist, Women's Hospital, New York City.

SIDNEY I. SILVERMAN, D.D.S. Assistant Clinical Professor, Denture Prosthesis, New York University College of Dentistry and Assistant Clinical Professor, Physical Medicine and Rehabilitation, New York Medical College, Flower and Fifth Avenue Hospitals. Consultant in Prosthodontia, Veterans Administration Hospital, New York City. Attending Prosthodontist, Bird S. Coler Hospital and Home Metropolitan Hospital, New York City, and Jewish Chronic Disease Hospital, Brooklyn, New York.

BRUCE B. SMITH, D.M.D., F.A.C.D., F.I.C.D. Clinical Associate (part-time), Operatives and Ceramics, University of Washington School of Dentistry.

VINCENT R. TRAPOZZANO, D.D.S. St. Petersburg, Florida. Former Professor of Prosthetic Dentistry, University of Pennsylvania School of Dentistry. Consultant, Veterans Administration Hospital, Bay Pines, Florida.

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Foreword

Dentistry during the past fifty years has become a dynamic profession. This is demonstrated by its use of an ever-expanding accumulation of knowledge toward the solution of its problems and the resulting improvement of its service to the public. Unfortunately, the breadth of dentistry, coupled with this growing accumulation of knowledge in the various divisions of dentistry, presents a problem to the profession. The practitioner finds it constantly more difficult to study, evaluate and use this information that is being presented to him in such great quantities by the investigator and his fellow clinicians.

This symposium on operative dentistry was prepared for the busy practitioner, that he might more easily acquaint himself with the opinions of experienced clinicians concerning the evaluations and applications of many of the newer ideas in operative procedure. Each clinician was selected with careful consideration for his achievements in his respective area of operative procedure and his experience in the practical application of what may be called "standard concepts" into which he has incorporated the newer ideas and principles.

These articles should clarify the new information and demonstrate how it may be used in the practice of dentistry. The editors and contributing authors hope to help eliminate some of the time-consuming, expensive and often frustrating experiences which may occur when the busy operator begins the use of many of the newly advocated materials, procedures, and techniques.

As the first Consulting Editor for operative dentistry, I wish to express my gratitude to the contributing authors for their enlightening articles.

Drexell A. Boyd, D.D.S.
Professor and Chairman
Department of Operative Dentistry
Indiana University School of Dentistry

Present-day Concepts of Cavity Preparation

ARTHUR B. GABEL, D.D.S., M.A.*

The preparation of the cavity is one of the most difficult and one of the most important operations performed by the dentist.

Its form is determined by certain biological factors such as the shape of the tooth, the size and shape of the pulp chamber, the location and extent of the carious lesion, the age and caries susceptibility of the patient, and by a number of mechanical considerations.

Among the mechanical factors are the probable approximate directions and magnitudes of the forces which will act on the restored tooth, the amount and distribution of the remaining sound dentin and the physical properties of the material to be used for the restoration.

In the average case an idealized cavity form can take care of these factors provided it is based on sound mechanical principles. Many cases, however, require a careful analysis of conditions and an individual design to meet them.

Given the prepared cavity, the restoration of the tooth is largely a matter of technique in which little depends on the judgment of the operator, since the contour and the occlusal anatomy are largely predetermined.

In general, the objectives of cavity preparation are to remove all decay and give the necessary protection to the pulp; to locate the margins of the restoration in relatively immune areas of the tooth; to form the cavity so that the tooth and the restoration will not fracture under the force of mastication and so that the restoration will not be displaced by it.

INSTRUMENTS AND INSTRUMENTATION

The detailed techniques of cavity preparation vary with the type of cavity and the method used to remove tooth structure. The latter usu-

* Edwin T. Darby Professor of Operative Dentistry and Chairman of Department, University of Pennsylvania School of Dentistry.

ally involves the use of a combination of hand instruments and rotary instruments such as burs, carborundum or diamond points and disks and, more recently, Airdent and Cavitron. The last two are discussed in another article in this symposium.

The speed of rotary instruments may vary from around 4000 rpm to over 100,000 rpm. High speed rotary tools and their use in cavity preparation are discussed in two accompanying articles. This discussion will be concerned with basic techniques using the higher conventional speeds of rotation, i.e., something under 10,000 rpm.

Steel burs and tungsten-carbide burs of the same design cut dentin with the same efficiency but tungsten-carbide far outlasts steel, the efficiency of which falls off rapidly. Neither of these burs performs well or retains its efficiency when cutting enamel, though the tungsten-carbide bur is far superior to the steel bur.

The fact that burs cut enamel comparatively poorly and have a much shorter life than when cutting dentin forces one to the conclusion that the fissure bur is not indicated for extending cavities into sound tooth structure. For this the enamel should be penetrated with an abrasive, preferably a diamond, point where the area of decay can be reached only by going through sound enamel and the extension carried out by undermining the enamel with an inverted-cone bur of the proper size. In this connection Henry and Peyton[4] found that "Although the No. 37 bur has only about one third as much active area as the No. 557 fissure bur, it is capable of removing approximately five times the amount of material per unit time as the fissure bur."

The rubber dam should preferably be used. The time consumed in placing it by one accustomed to its use is more than made up by ease of operating, increased visibility and absence of patient interruption by spitting and/or conversation. Where the diamond point is indicated to reach the dentin it should be used before the dam is applied, because water must be used as a coolant. Attachments for this purpose are available, or an assistant may use the water syringe for the short time it is required.

BASIC PRINCIPLES COMMON TO ALL TYPES OF CAVITIES

The technique of cavity preparation varies for each type of cavity, although certain basic principles apply equally to all types. Two of these principles relate to the preparation of the enamel walls of the cavity and depend only on the direction of the enamel rods and the material used for the restoration.

Enamel rods, the inner ends of which are not supported on sound dentin (Fig. 1), shear readily because they are then able to resist a

force applied to their outer ends only by the shear resistance of the inter-prismatic substance. As a consequence, any rods, the inner ends of which lie in the enamel wall of a cavity, may shear, resulting in a V-shaped ditch along the margin of the restoration. A knowledge of the directions of the rods in various parts of the teeth is essential.

Practically, the removal of these rods, which is known as planing the enamel walls, is simple. A sharp chisel or hatchet applied to the enamel near the cavity margin will readily shear off these rods along the plane of cleavage, i.e., the direction of the rods. This operation should be repeated until the bevel produced by this planing extends

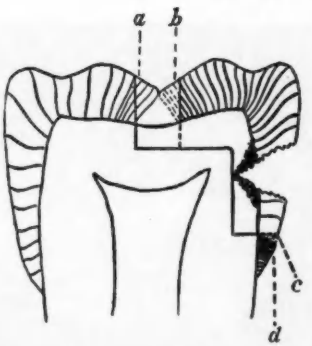

Fig. 1. Directions of enamel rods in relation to cavity walls. *a* and *d* show correct planing which leaves no unsupported rods. *b* and *c* are incorrect and have rods with inner ends in cavity walls.

to the dento-enamel junction, after which the enamel rods will not shear without the application of excessive force. This method is preferable to using a stone because the stone will abrade the rods to conform to any angle regardless of their direction.

It is obvious that in parts of the tooth where the rods slope from the dentin toward the cavity wall, shearing will not take place and all that is necessary is to obtain the desired smoothness of the wall.

The above procedure is distinct from forming the cavosurface bevel, which is determined by the "edge strength" of the restorative material. Normally the cavosurface angle approximates a right angle. If it is bevelled the margin of the restoration becomes acute while the angles the bevel makes with the inner and outer enamel surfaces become obtuse. The enamel is therefore greatly strengthened besides being protected by the overlying restorative material. However, the margin of the restoration is weakened at the resulting thin edge, and, unless the material is tough, will fracture. Therefore, the cavosurface angle

should be bevelled only when the material is stronger than the enamel. This is true only of gold foil and the gold inlay.

The cavosurface bevel may be obtained by passing the blade of a chisel along the cavosurface angle so as to make an angle of approximately 45 degrees with the outer surface of the enamel. A cylindrical stone with the axis held at the same angle may also be used.

THE CLASS I CAVITY

The class I cavity includes all pit and fissure cavities, i.e., those occurring on the occlusal surfaces of molars and bicuspids, the buccal

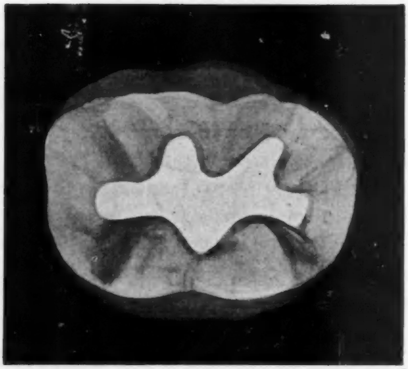

Fig. 2. Completed medium-sized class I cavity in mandibular molar, showing conservative cutting following course of fissures.

grooves of mandibular molars, the distolingual grooves of maxillary molars and the lingual surfaces of maxillary incisors.

The outline form of these cavities does not require extension for prevention because they are on the least caries-susceptible areas of the tooth. They result from the enamel defects which retain food debris. All that is required in the average case is to remove all undermined enamel and to follow out fissures so as to eliminate any defect that would result from a fissure's breaking the continuity of an enamel wall.

The outline of an occlusal cavity in a molar or bicuspid should not cut squarely across the triangular ridges of the cusps (Fig. 2) but should follow a contour line, thereby saving tooth structure, improving esthetics and, probably most important, giving a stronger restoration because of its more nearly uniform thickness.

In opening and extending a class I cavity all undermined enamel should first be broken down with straight, bin-angle or Wedelstaedt

chisels or hatchets. Where fissures are to be followed out a No. 35 or No. 37 inverted-cone bur, depending on the size of the desired cavity, should be started approximately 1 mm. deep in the dentin and should follow out the fissures with light lateral pressure, being withdrawn at the same time so as to remove the undermined rods.

Where there is only incipient decay and the enamel cannot be broken down with hand instruments, a small knife-edged diamond wheel should be used to reach the dentin, after which the preparation is continued with an inverted-cone bur as just described.

In larger occlusal cavities in molars the undermined enamel should be broken down and decay excavated with spoon excavators. This will leave a concave pulpal floor. This concavity should be filled with zinc phosphate cement up to a level approximately 1 mm. below the dento-enamel junction. If the depth is sufficient a thin layer of zinc oxide—eugenol cement should be placed in the deepest part of the concavity. Fissures should now be carried out as described and a shelf of flat dentin should surround the cement floor or be cut at at least three points so as to provide a firm, stable base on dentin[3] for the restoration.

The cavosurface angle should be bevelled for foil but not for amalgam. Chisels or hard-bits are preferable except at the ends of narrow cuts following out fissures. Here a small cylindrical or tapered carborundum or diamond point will eliminate any break in the continuity of a smooth margin.

If the preparation is for an inlay, the undercut produced by the inverted cone bur is removed and the proper taper of approximately 5 degrees may be made with a wet cylindical or tapered carborundum or diamond point. A cavosurface bevel is formed as for gold foil.

When large occlusal cavities approach the tips of cusps, particular care must be taken to remove unsupported enamel rods. In many cases it may be preferable to remove the whole cusp and to prepare a seat at sufficient depth to provide strength for this part of the restoration. Amalgam requires considerably greater depth than an inlay.

THE CLASS II CAVITY

General Principles

The class II cavity, which occurs in the mesial and distal surfaces of molars and bicuspids, is a smooth-surface cavity and therefore must be extended into relatively immune areas according to the principles of extension for prevention.

Where the cavity margins should be placed depends, in the case of buccal and lingual margins, on the buccolingual curvature of the tooth

and, in the case of the gingival margin, on the extent to which the dental papilla fills the embrasure and in older individuals, on the occlusogingival curvature.

A minimal amount of extension requires that the margins be sufficiently in the clear for finishing and inspection. Factors which would determine whether further extension is necessary are caries susceptibility and oral hygiene. In many cases rotation or tipping of the involved tooth or of the adjacent one complicates the case so that the best result obtainable is a compromise.

Clinical experience and mechanical principles indicate that the class II cavity preparation must have an occlusal lock to resist the horizontal components of force resulting from opposing cusps contacting triangular and marginal ridges. This may mean removal of considerable sound tooth structure from the occlusal surface unless this surface is affected by pit and fissure caries.

Regardless of initial conditions, the placing of the occlusal lock may introduce complicating factors. When a restorative material much stiffer than dentin is used, the proximal portion of the restoration between the pulpal and gingival floors compresses less than the dentin between the same levels. This depression of the pulpal floor causes the gingival portions of the MO, DO or MOD restoration to tend to rotate out of the cavity about an axis near the axiopulpal line angle. This rotation should be prevented by retention at the gingival floor where it has greatest mechanical advantage.

It is doubtful if the difference in stiffness between dentin and either amalgam or foil is great enough to cause rotation but, if it were, the undercuts and wedging of the material would prevent it. Inlay gold, however, is 10 to 15 times as stiff as dentin and is not retained by undercuts or wedging. It, therefore, calls for gingival retention. This may be obtained by giving the gingival floor a rootwise slope in the dentin from a point near the dento-enamel junction to the axial wall. The result of locking the gingival portion is a bending of the restoration at the axiopulpal line angle. For this reason this angle should be well rounded for additional strength.

The opening of a class II cavity follows the same principle as for the class I. Undermined enamel, if present, should first be broken down with the hand instruments named. This step may often be carried out in both the occlusal and the proximal portions so that there is direct access to the decayed area. The carious material should then be removed with a spoon excavator and the outline form should be completed in the manner to be described.

If the occlusal surface is intact or only fissured, a small knife-edge diamond wheel should be used to reach the dentin, after which a No.

35 or No. 37 inverted cone bur, as for the class I cavity, should be used to cut through the marginal ridge over the decayed area. If the decay is covered with sound dentin it should be opened into with a No. 2 or No. 4 round bur, which should penetrate the dentin in a gingival direction. The opening should be enlarged the full extent of the decayed area by removing all undermined enamel buccally, lingually and gingivally with enamel hatchets 10-6-12 R and L or 15-8-12 R and L. The remaining debris should be removed with spoon excavators.

Extension into sound dentin beyond the area of decay, if required for prevention, should be carried out by sweeping a No. 35 (in small

Fig. 3.

Fig. 4.

Fig. 3. A completed class II cavity in maxillary bicuspid.

Fig. 4. Completed class II cavity showing formation of triangular areas mutually perpendicular to the axial wall by removal of triangular pyramids of dentin.

teeth a No. 34) inverted cone bur buccolingually through an arc, keeping it in contact with the proximal enamel and advancing gingivally. The undermined enamel should then be removed with hatchets in the same way as the enamel undermined by decay. This process is repeated until the desired buccolingual and gingival extension is obtained. The buccal and lingual dentin and enamel walls should, at this stage, lie in the same plane, i.e., the plane of the finished enamel walls.

Foil and Amalgam

For foil and amalgam restorations the buccolingual width of the proximal part of the cavity should be increased as the gingival margin

is approached so that the buccal and lingual walls converge from the gingival to the occlusal surface (Fig. 3).

The width at the gingival wall should be determined by the principle of extension for prevention, the convergence occlusally by the same principle but also by the increase in thickness of the enamel cap and the decrease in the buccolingual dimension of the dentin body of the tooth. The increased cross-section at the gingival wall reduces the stress in the restoration and consequently reduces the flow of amalgam. The decreased buccolingual dimension at the occlusal surface leaves stronger buccal and lingual walls and the decreased area results in less load being applied to the restoration, an important point where the material is amalgam.

The buccal and lingual walls, while converging occlusally, are now probably at more than 90 degrees to the axial wall and the proximal part of the cavity has no retention.

For foil the buccal and lingual walls should be perpendicular to the axial wall. This perpendicularity may be obtained by removing small triangular pyramids of dentin (Fig. 4) so that the apices are at the pulpal floor, the bases at the gingival floor and the axial walls in the plane of the existing axial wall. The internal buccal and lingual dentin walls should be extended nearly (but not quite) to the dento-enamel junction at the gingival floor. This may be done with enamel hatchets for the buccal and lingual walls and hoes and bin-angle chisels for the axial wall in the mandibular teeth, and with hoes and bin-angle or Wedelstaedt chisels in the maxillary teeth. This technique will give the sharp angles necessary for starting gold foil.

For amalgam the axiobuccal and axiolingual line angles should be made acute. The same instruments may be used as for the gold foil cavity.

An alternative method for amalgam is to use a No. 33½, No. 34 or No. 35 inverted-cone bur, depending on the size of the tooth and the depth of the cavity, and, starting at the gingival floor, to cut to a depth equal to the full radius of the bur, gradually reducing the depth of the cut to zero at the pulpal floor. All cuts should be at the expense of the buccal and lingual walls, not the axial.

For both amalgam and foil the final step before the toilet of the cavity should be the finishing of the margins. The enamel walls at the gingival cavosurface angle should be planed with gingival margin trimmers, 15-80-8-12 R and L or 20-80-9-12 R and L for mesial cavities and 15-95-8-12 R and L or 20-95-9-12 R and L for distal cavities. The buccal and lingual enamel walls were planed while obtaining the outline form. The cavosurface angle of the occlusal portion should be treated the same as that of a class I cavity.

Gold Inlay

Because of the necessity of taking an impression of the cavity or of making a wax pattern, and to permit the seating of the inlay, the axial walls of the inlay cavity must have a slight divergence (Fig. 5) (3 to 5 degrees), otherwise the preparation is the same as for amalgam or foil up to the point of establishing retention in the proximal portion.

This divergence is obtained on the occlusal surface with tapered carborundum or diamond points as for the class I inlay cavity.

In extending the proximal portions the enamel overlying sound dentin should be undermined as for foil or amalgam except that the

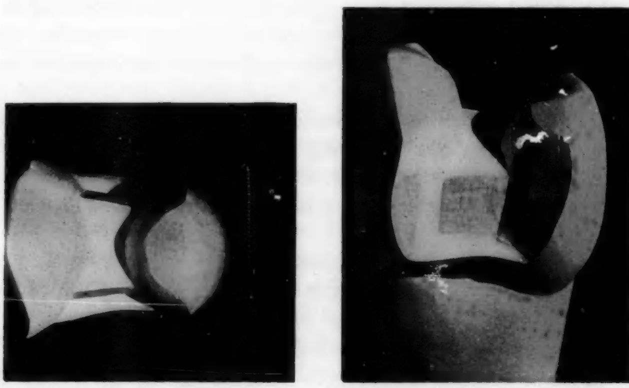

Fig. 5. Occlusal and proximal views of a form of inlay cavity box preparation.

slope of the buccal and lingual walls is reversed, diverging from the gingival to the occlusal. The angle between the walls should be about 5 degrees. The walls may be finished with tapered points.

Gingival retention, as previously pointed out, should be provided in the class II inlay cavity. This may be done in several ways but a simple method which has proved satisfactory in thousands of inlays is to use distal gingival margin trimmers 15-95-8-12 R and L or 20-95-9-12 R and L in mesial cavities and mesial trimmers 15-80-8-12 R and L or 20-80-9-12 R and L in distal cavities. By placing the narrow side of the blade against the axial wall and sweeping the edges of the blades buccolingually across the gingival floor a reverse bevel will be obtained. This bevel should extend a little short of the dento-enamel junction. Care must be taken not to get undercuts in the buccal and lingual walls.

Up to this point the preparation of the direct and indirect cavities

is the same. In both cases it is desirable that the cavity margins be prepared to give a definite seat to the casting at the buccal, lingual and gingival cavosurface angles. In the indirect preparation the slice provides this seat. But the ordinary cavosurface bevel will not provide it for the direct preparation, since to carry this bevel beyond the greatest mesiodistal diameter of the tooth would produce an undercut.

To produce the desired bevel for the direct preparation, ½ inch fine sandpaper "wet or dry" disks can be used. The disk should be held so as to make buccal and lingual bevels, the planes of which should make slightly greater angles with a vertical mesiodistal plane than the enamel rods in the enamel walls thus formed. These bevels should extend to the gingival floor (Fig. 5) and merge at the buccogingival and linguogingival line angles with the bevel produced at the gingival cavosurface angle by the gingival margin trimmers, which should be used in the same manner as for foil and amalgam preparations.

For an MOD cavity the buccal and lingual bevels should also have slight mesial or distal slopes, giving a slight taper to the preparation so that the entire cavity can be seen from the occlusal aspect. In this way a complete cavosurface bevel is produced and all undercuts are eliminated.

The indirect preparation is the same as the direct in every respect except that the excessive contour is reduced by slicing the proximal surfaces. The slices can be vertical for an MO or DO preparation but should converge slightly (3 to 5 degrees) for an MOD. They should extend ½ to 1 mm. below the gingival floor. No planing of the gingival enamel is necessary, because this is removed in the slicing.

Safe-sided ¾ inch or ⅝ inch carborundum disks in straight handpieces, contra-angle or one of the special attachments are satisfactory for this operation.

THE CLASS III CAVITY

The class III cavity is a smooth-surface cavity and its extension is based on the same general principles as that of the class II cavity. Care must be taken to extend the margins incisally from the contact point. If the material of choice is gold foil, for better esthetics the additional extension necessary for access should be from the lingual surface unless the labial surface is extensively involved by caries.

Gold Foil

The technique is much the same as for the proximal part of the class II cavity, except that the approach is on the lingual or/and labial

surface. Undermined enamel is broken down with chisels or hoes and the caries is excavated with spoon excavators. Extension is carried gingivally, labially and lingually by undermining the enamel with small inverted-cone burs and removing the enamel with chisels or hoes. Extension incisally is carried out in the same way. For smoothing the labial, lingual and gingival dentin walls and sharpening the line angles, revised Woodbury chisels 8-80-3-9 R and L or 10-50-4-6 R and L are preferable. The axial wall should be finished with a 6-2-23 or 4-1-23 hoe. The incisal retention must be in dentin and is made with a small round bur. It should be large enough to admit the point of the plugger to be used.

The labial and lingual walls must be perpendicular to the axial wall if it is flat, or to a tangent to that wall if it is convex. If the cavity is extensive it is necessary to give it retention form in the gingival portion by making acute angles at the expense of the labial and lingual walls with the Woodbury chisels or a No. 33½ inverted-cone bur.

The labial, lingual and gingival enamel walls should be planed to remove unsupported rods. The gingival margin is planed with the Woodbury chisels used oppositely than when forming the gingival wall. The labial and lingual margins are finished with chisels or hardbits. Particular care must be taken to remove unsupported rods at the incisal angle and the lingual marginal ridges because of the rapid change in their directions at these points.

Silicate Cement

Silicate cement is more soluble than enamel and is more damaging to the pulp when in contact with freshly cut dentinal tubules than with tubules whose pulpal ends are partially closed by secondary dentin. Therefore, extension should be only enough to place the margins where access for finishing the restoration and for periodic examination is possible. The axiolabial and axiolingual line angles should be made acute for retention, since silicate shrinks. Otherwise the preparation is the same as for gold foil.

Class III Gold Inlay

The preparation of the inlay cavity in the maxillary teeth follows the same general principles except that access is always from the lingual aspect and all walls must diverge from the labial to the lingual surface so that the wax pattern may be withdrawn in the lingual direction. This is done with a tapered fissure bur by working

from the lingual aspect and removing every trace of a lingual wall from gingival to incisal margins, at the same time leaving as much labial wall as possible. The gingival wall should slope apically as the axial wall and the lingual cavosurface angle are approached; also, it may be grooved along the axiogingival line angle with a tapered bur. A tapered groove should be cut in the dentin in the incisal surface (Fig. 6). All incisal and gingival surfaces should diverge from the labial. For increased retention a lingual lock is frequently added as for a class IV preparation (to be discussed).

Fig. 6.

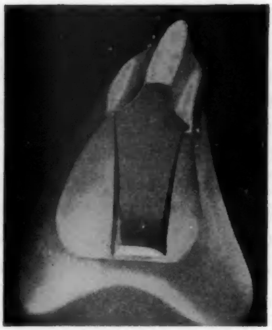

Fig. 7.

Fig. 6. A class III inlay cavity preparation.
Fig. 7. A class IV inlay cavity preparation in a mandibular incisor.

All enamel walls must be planed to remove unsupported rods and must be completely visible from the lingual aspect. They may be finished with chisels or hard-bits or with carborundum or diamond tapered points. If the latter are used care must be taken that they are held at such an angle as to leave no unsupported rods. With the beveling of the lingual cavosurface angle this treatment will give a sealing bevel to the entire casting.

THE CLASS IV INLAY CAVITY

Maxillary Teeth

When the incisal edge of a maxillary anterior tooth is involved, the retention lost thereby is obtained by cutting a dovetailed lock on the lingual surface.

The lock must be in dentin and should be as close to the incisal edge as the anatomy of the tooth will permit. It is made by starting

a cut in the axial wall with a No. 34 inverted-cone bur held perpendicular to the lingual surface at a depth in the dentin not to exceed the length of the bur head. The enamel is undermined and removed and the walls are given the correct taper as described for the class I and class II inlay cavity. Care must be taken that the taper of the side walls of the lock permits withdrawal of the pattern without distortion.

The lingual bevel at the incisal corner should be increased so as to allow for increased thickness of the casting at this point.

Mandibular Cuspids

Because of the lingual component of force acting on the mandibular anterior teeth, the lingual lock is contraindicated.

For cuspids, because of their greater labiolingual thickness, the incisal lock may be used. This should extend at a uniform depth beyond the tip of the cusp and should leave the lingual wall slightly higher than the labial.

The incisal edge is taken down with carborundum or diamond wheels into the dentin far enough to give sufficient width between the enamel walls. A groove is then cut with a No. 34 inverted-cone bur in the dentin, leaving the buccal and, even more important, the lingual enamel supported by dentin. The sides are given the proper taper with a tapered fissure bur or small tapered carborundum or diamond points.

Mandibular Incisors

Because of the small labiolingual diameter of the mandibular incisors, incisal retention is contraindicated.

Instead of cutting between the enamel plates, the incisal tip of the tooth should be capped. After preparation of a proximal box and a slice as for the class II indirect preparation on a miniature scale, the incisal edge is taken down enough with a carborundum or diamond wheel to give sufficient clearance for the casting. The enamel is then partially removed across the incisal edge with the same wheel for 1 to 1½ mm. on the labial surface and somewhat less on the lingual surface. These cuts terminate as finishing lines (Fig. 7). If the cavity is an MID these cuts join the mesial and distal portions. If it is an MI or a DI they must be joined on the distal or mesial surface, respectively, by cutting interproximally with a safe-sided and/or paper disk, giving the same taper to this surface as to the labial and lingual surfaces.

THE CLASS V CAVITY

Class V cavities are those appearing on the gingival third—not pit and fissure cavities—of the buccal, labial and lingual surfaces of all of the teeth.

Cavities of this type are opened in the usual manner, i.e., by breaking down undermined enamel, excavating decay and extending into sound tooth structure by undermining with an inverted-cone bur and withdrawing the bur to remove the undermined rods.

For prevention of the recurrence of caries the cavity should be extended close to but not to the axial angles of the tooth. In young individuals it should be extended under the free margin of the gingiva. In older individuals the gingival extension should be determined by the decay. No occlusal extension is required.

The axial wall should follow the contour of the tooth. For gold foil the side walls of the cavity should be perpendicular to a plane tangent to the axial wall at its mid-point. For amalgam, retention may be cut with a No. 34 inverted-cone bur around the line angle formed by the axial and side walls. For the gold inlay these walls should diverge about 3 degrees.

The mesial, distal and gingival (and in large cavities, the occlusal) enamel walls should be planed using hoes, chisels or hard-bits, and for gold foil and the gold inlay the cavosurface angle should be bevelled.

The inlay preparation is contraindicated for mandibular incisors, because these teeth may bend[2] under the lingual component of the masticatory force and cause the inlay to be displaced.

SUMMARY

The methods and principles of cavity preparation as discussed here have a firm biological and mechanical foundation. The nature and structure of the tooth and the physical properties of the materials are considered in relation to the forces applied to the tooth and the form of the cavity required.

It is pointed out that steel and tungsten burs do not cut enamel as effectively as they do dentin and hence should be used only to cut the latter, while abrasive tools should be used for removing enamel.

So-called "high speed" cutting tools are not discussed, but it seems obvious that the use of these tools will not change cavity design, because the design depends only on conditions inherent in the case and not on the instruments employed.

Figures 1, 2, 3, 4, and 7 in this article are from Gabel, A. B. (ed.): American Textbook of Operative Dentistry, 9th ed. (Philadelphia, Lea & Febiger, 1954.) Figures 5 and 6 are from Dr. Edwin S. Smyd's chapter in the American Textbook of Operative Dentistry.

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40th and Spruce Streets
Philadelphia, Penna.

Principles Associated with the Use of High Speed Rotary Instruments

ROBERT E. DOERR, D.D.S., M.S.

During the past several years the attention of the dental profession has been directed to the use of higher speeds for rotary cutting instruments. The interest in this subject has been tremendous, as is evidenced by the large number of clinics that have been presented and by the great amount of literature that has been written pertaining to this area. Much investigation and research have been and are currently being done, in order to perfect equipment and cutting instruments and in order to ensure that the use of higher speeds is based upon sound biologic and physiologic principles. Despite this emphasis, it has been estimated by various dental manufacturers that not more than 20 per cent of the dentists engaged in private practice are using some form of high speed.

The purpose of this paper is to discuss the practical and basic principles that are associated with the use of high speed rotary instruments. It is hoped that more dentists will be stimulated and encouraged to use high speed, even in its most modest form, and by doing so avail themselves of its advantages.

VIBRATION

Walsh and Symmons[15] determined that vibrations of 100 to 200 cycles per second caused the most discomfort to patients and that vibrations above 1000 cycles per second are usually beyond the perception of the average person. It is interesting to note that, even when operating with speed that will produce vibrations above this threshold, eccentricities in the cutting instrument or equipment can cause a basic or fundamental vibration that is extremely annoying to the patient. Utmost care must be taken to see that all equipment is functioning smoothly and properly. A vibration that is noticeable to the operator is amplified many times by the sensory mechanisms of the patient.

Vibration is affected by the type of handpiece, contra-angle and cutting instrument that is used. It is believed by many dentists who are using high speed that the sleeve-type contra-angle, or angle handpiece, offers an appreciable reduction in vibration over the conventional, or short type, contra-angle. Even though it is argued by some manufacturers that the added length of the angle handpiece does not provide for better alignment of the shafts, the least it does is to offer protection to the back shaft of the angle from being damaged by inadvertent dropping or by careless handling in the maintenance of the instrument. Friction bearings create less vibration than do ball bearings; however, ball bearings have been utilized in several high speed handpieces because they will tolerate higher speeds without heating excessively. Assuming concentricity, good quality diamond instruments cause less vibration than do burs and for this reason many dentists prefer to use diamonds as much as possible in the preparation of cavities.

It has been determined by Henry and Peyton[4] that the main source of vibration is not from the cutting action of the instrument on the tooth, but from the equipment. Eccentricities in the motor pulley and engine arm pulleys are transmitted through the belt to the handpiece and, hence, to the operator and the patient. The engine belt itself will cause vibration, and so it is important to select a belt that does not possess thick spots, particularly at the splice. Increasing the tension on the belt reduces its vibration, but too much tension detracts from the maximum speed of the unit by several thousand revolutions per minute. Excessive belt tension also causes unnecessary wear of the bearings in the dental motor and handpiece.

Vibration is characterized by both its amplitude and its frequency. As the number of revolutions per minute is increased so is the frequency of any vibration present, while the amplitude or intensity of the vibration is decreased. With high speed equipment that is functioning correctly it is possible to increase the frequency and decrease the amplitude of vibration to the extent that it is no longer perceptible to the patient.

GENERATION OF HEAT

The need for some type of coolant to control temperature rise during cavity preparation with higher speeds has been demonstrated by a number of investigators, and it is something that is not difficult to judge clinically. Henschel,[5] Lieber,[9] Panzer,[10] Peyton,[11] and Hudson[6] are but a few who have advocated the use of a coolant to dissipate the heat that is generated and thus prevent injury to the pulp. Clinical experience utilizing the higher speeds of rotation also points to the need for some type of temperature control.

The size, sharpness, speed of rotation, amount of pressure, and length of time that pressure is applied on the instrument are the factors that are generally regarded as having the most influence on the thermal change. Large-diameter instruments cause a greater temperature rise than do smaller instruments, because of the greater area of tooth tissue contacted. Burs and diamond points that are dull cause an increase in temperature because they do not cut effectively and their energy is wasted as heat. Operating with conventional speeds and according to basic fundamentals does not produce temperatures that are injurious to the pulp. However, at speeds of 10,000 rpm and above, it becomes mandatory to use a coolant even though light operating pressure is employed and a relatively short time is spent in the actual cutting operation.

Every dentist is aware of the fact that dentin is an excellent insulating medium, but some fail to realize that because of its excellent insulating qualities dentin also retains heat. Intermittent operating with increased speeds is not sufficient to counteract the build-up of temperature in the dentin. Henschel[5] determined in his investigations that dentin possesses an average thermal tolerance zone of 85° to 130° F., and that any rapid change causes a proportionate degree of pain as the temperature goes above or falls below these extremes. At higher speeds temperature increases of several hundred degrees have been recorded when cutting dentin or enamel, or both, so it becomes obvious that the insulating quality of dentin cannot be relied upon to furnish adequate pulpal protection. There is a greater temperature rise when cutting enamel than when cutting dentin.

The most common coolants are air, water, and the air-water spray. Air is not a satisfactory coolant since it fails to control temperature rise at higher speeds, and its desiccation of the dentin may cause pulpal irritation. Water and the air-water spray are the coolants of choice for high speed, and their use will be discussed in more detail.

Water must be adjusted to a much greater volume to accomplish the same degree of cooling that can be achieved with a relatively small volume of water mixed with air. When using Thompson's[14] "washed field technique," water is preferred to the air-water spray as it is more easily recovered. Copious amounts of 200 to 250 cc. per minute are necessary to dissipate the heat of cutting before the coolant is evacuated. When less water is used it is recovered by the unit before it can act as a coolant. In the absence of an efficient evacuating unit, water should be adjusted to flow at approximately 50 to 60 cc. per minute. With conventional saliva ejectors this amount of water is sometimes sufficient to fill the patient's mouth and cause a choking sensation. To prevent excessive cooling and resultant pain the water should be warmed to approximately 100° F.

Unless an efficient means for recovering the water is used it does not keep the cavity as clean as does the air-water spray. The spray should be adjusted to deliver 6 to 8 cc. of water per minute, and the water should be preheated to approximately 130° F.

Coolants should be directed on the cutting instrument so that they are carried into the preparation and not thrown off by centrifugal force. Care must be taken when using the "washed field technique"[14] to direct the water stream so that it will not be evacuated before it has functioned as a coolant. According to investigation that is currently being done by Peyton[12] and his associates, it appears as though either water or the air-water spray, if used correctly, will prevent an injurious generation of heat even at speeds in the 100,000 rpm range.

In addition to eliminating dangerous heat generation and keeping the cavity cleaned out, the use of coolants offers certain other advantages: (1) It prevents the rotating instruments from becoming clogged with debris and subsequently losing their efficiency. (2) It increases instrument life because the cutting instruments do not have to be subjected to cleaning operations that tend to dull them. (3) It lubricates the cutting operation and facilitates the removal of old restorations. (4) It causes less need for local anesthesia, thus allowing the pulp to respond normally to the trauma of the operation without first being influenced by a vasoconstrictor. (5) It creates a psychological benefit if patients either control, or are allowed to think that they control, the flow of the coolant. Their cooperation is encouraged and their attention is distracted from the operative procedure.

CUTTING EFFICIENCY

The cutting efficiency of an instrument is described as the ability of the instrument to remove a maximal amount of tooth tissue with a minimal amount of effort and time involved. It is of significance to the dentist that the functional life of an instrument is interrelated with its cutting efficiency.

Carbide Burs

Design Factors. From the standpoint of design there are several factors that are important when considering the operation of a bur. These significant features are the number of flutes, the angle at which the flutes are formed (rake angle), the amount of chip space (clearance angle), and the diameter of the bur.

A lesser number of flutes on a bur creates larger chip spaces and the size of the chip that can be removed is increased. The larger the

chip the more heat energy it carries with it so that less temperature rise is caused. Experimentation with burs having fewer than the conventional number of flutes has shown that they produce more vibration.

The rake angle may be defined as the angle formed between the leading face of the flute, or tooth, and the radius of the bur. The clearance angle is the angle formed between a line drawn at right angles to the radius of the bur and the trailing face of the flute. According to Henry and Peyton,[2] "the more positive the rake angle, the more effective is the cutting action of the tooth; while the more negative the rake angle, the less effective is the cutting action of the tooth. . . . In bur design, there is probably a proper balance between the rake angle and clearance space which gives effectiveness and life to the instrument when operated at various speeds and pressures." If the rake angle is too positive, the flute is weakened and the cutting edge will be broken or damaged. Burs are designed to cut most efficiently when rotating in a clockwise direction. The operator can examine a bur with a magnifying glass and determine if it is designed to be a good cutting instrument, or if it appears as though it was designed to abrade or rub the tooth tissue away. Such an examination will also reveal any major imperfections in machining that may exist. Carbide burs in the dental armamentarium should be examined routinely under magnification to check for broken or chipped flutes, or other evidences of eccentricity.

The investigations of Henry and Peyton[2] demonstrated that the most efficient bur design is the inverted cone and that the most efficient size within the series is the No. 37. Even though it possesses only one-third of the cutting area of a No. 557 it is five times as effective. In their studies Henry and Peyton[3] also determined that, when other factors remain constant, there is a proportionate ratio between the amount of material removed and the diameter of the bur.

Tests have shown that burs vary markedly in their efficiency, both from one manufacturer's products to another's, and within the same product, from one series to another. It should be understood that the problems encompassed in manufacturing a bur are many and difficult, and that much research is being done to develop a design that will be more effective and satisfactory at higher speeds of rotation.

Carbide vs. Steel. The carbide bur is more adequate than the steel bur at any speed, and at higher speeds its use is mandatory if desirable results are to be obtained. When it first begins to cut in relatively soft material such as dentin, the steel bur possesses approximately the same efficiency as the carbide bur; however, this efficiency is lost in a matter of moments. In a clinical experiment, Kutscher[8] cut an average

of 0.87 tooth surfaces with a steel bur while a carbide bur cut an average of 19.71 surfaces. Because it is more efficient, the carbide bur generates less heat than the steel bur.

Efficiency in Dentin and in Enamel. Carbide burs cut best in dentin and less well in enamel. They are more adequate for operating in dentin than comparably sized diamond instruments. Despite this observation, many operators use the smaller diamond instruments for the internal portions of cavity preparations, particularly when operating with speeds of 45,000 rpm and above. These dentists claim greater patient comfort and convenience of design as the main reasons for their choice, not greater efficiency.

Optimal Speed. The speed at which carbides cut most efficiently is puzzling. It was at first thought to be around 15,000 rpm, but it appears now as though the peaks of efficiency may occur in cycles, and that the most efficient speed is much higher than supposed. Investigation done at the Bureau of Standards by Hudson and Sweeney[7] shows that the time required to make a cut 0.15 inch deep decreases rapidly as the speed is increased to 12,000 rpm. At 2000 rpm the cut required 28.7 seconds, at 12,000 rpm 3.6 seconds, and at 24,000 rpm approximately 1 second. For the cut that was being made these figures indicate that at 24,000 rpm the cutting rate of the bur was so rapid that, practically speaking, not much further saving of time was possible.

Regardless of the speed that is eventually determined as being the most efficient, the cutting rate of carbide burs is increased tremendously at the extremely high, or super, speeds. However, it is emphasized that efficiency and cutting rate are not one and the same.

Diamond Instruments

When selecting diamonds it should be recognized that the quality of the instrument determines to a great extent its efficiency. It is sound practice to examine diamond instruments under magnification before purchasing them. Such imperfections as eccentricities, uneven distribution of grit, blisters or bubbles in the binding agent, and variation in the size of the diamond particles can be detected with the aid of a pocket magnifying lens. A diamond instrument should be purchased as the result of careful, personal study and analysis and not solely because it happens to be used by someone else. Diamond points with rounded corners instead of sharp angles will provide better service because the grit is maintained much longer.

Diamond instruments are abrasive and cut enamel faster than dentin and, at speeds of 10,000 to 50,000 rpm, with many more times the efficiency of carbide burs. Basically, harder substances should be

abraded and softer substances should be milled. The effective cutting of an abrasive instrument depends upon its surface (or peripheral) speed. Because of this situation, the dentist should always use the largest diamond point possible, taking into consideration accessibility, convenience, and the amount of tooth tissue to be removed. Obviously, the surface speed of an instrument is effected by its concentricity. An instrument that is eccentric will cut only on its high spots.

Optimal Speed. There has not been as much laboratory investigation of diamond instruments as there has been of burs. The optimal speeds for various sizes of diamond points have not been determined, and there is conflicting opinion on the fineness of grit and its relation to the speed of the instruments. Chayes[1] reports the American Standards Association as indicating that the optimal speeds for diamond instruments are probably between 5000 and 9000 surface feet per minute. Such speeds would mean that instruments with a diameter of ½ inch should rotate at 40,000 to 70,000 rpm and that smaller diameter instruments should travel much faster. One of the greatest advantages to the development of equipment that will function at 150,000 to 200,000 rpm is that the small-diameter diamond point has been made more effective. Clinically, it seems that carbide burs have a greater cutting rate at the extremely high speeds than do diamonds. Diamond instruments are used many times at these speeds not because of their superior cutting ability, but because of their convenience of design and patient comfort.

Operating Pressure and Coolant. Absolute necessities for the efficient use of diamond instruments are light pressure and an adequate amount of coolant. Under these conditions diamond instruments can be used to cut amalgam, although they are not as satisfactory for this purpose as are carbide burs. At mouth temperature amalgam is brittle, but when heated it becomes malleable and will clog the diamond. Excessive pressure or lack of adequate coolant will also cause tooth tissue to be smeared into the grit, and will cause fracture and loss of diamond particles from the surface of the instrument. Observance of the rules of light pressure and adequate coolant will eliminate the necessity of cleaning diamonds routinely with an abrasive-type cleaner. The bonding agent of a diamond instrument can be worn away with the resultant loss of diamond grit and shortening of instrument life.

GENERAL PRINCIPLES

The most fundamental concept, and the one that the dentist must recognize and master, is that the higher the rotational speed of the

instrument the lighter must be the pressure that is applied. At conventional speeds 2 to 4 pounds of pressure is considered to be optimum, while at speeds of 10,000 to 12,000 rpm 8 to 12 ounces of pressure are used and at speeds in excess of 50,000 rpm only 1 to 2 ounces of pressure are necessary. The pressure should never be great enough to slow the instrument. When first beginning to work with increased speeds, it is a good policy to test hand pressure on a suitable scale or balance. Because of the light pressure necessary the instruments are more easily controlled, the instruments cut more effectively, there is less fatigue to the operator, and there is less apprehension on the part of the patient.

It is advisable to allow the instrument to gain maximal speed before contacting the tooth. If this procedure is not followed, the instrument will probably not attain maximal speed during the operation because of the low torque of the dental motor. There is also less discomfort to the patient if the tooth is contacted with the instrument revolving at high speed rather than gaining speed after it is in contact with the tissue.

Whenever possible, to gain more control, the instrument should be pulled toward the operator and into the tissue being cut. Tooth tissue is removed so rapidly at higher speeds that pushing on the instrument does not give the same measure of security. Where access and convenience permit, even greater accuracy and stability of the instrument can be accomplished by placing a finger of the opposite hand on the head of the contra-angle.

The speed of rotation should vary with the operation to be performed, the diameter of the instrument, the type and amount of tissue to be cut, the accessibility of the area, and the proximity to the pulp. High speed is not indicated for all operative procedures, and a complete range of speeds should always be available.

The most efficient results will be obtained by operating with continuous rather than intermittent pressures. It is essential that the rotating instrument be kept moving and in contact with the tooth tissue. Even though it is desirable to keep the instrument in motion, it is unnecessary to move the hand quickly. The movement of the hand can, and should, be rather deliberate.

After experimenting and familiarizing himself with higher speed, the operator will develop a more systematic approach to cavity preparation. Fewer rotary instruments will be needed, because each one operates more efficiently and completes the task for which it was designed. Rotary instruments of the highest quality are necessary for the most satisfactory utilization of high speed, and they can be no better than the handpiece in which they are used.

Contrary to what is frequently supposed, carbide burs and diamond instruments rotating at high speed do not leave a smoother surface than they do when run at conventional speeds. Neither is the surface affected by the presence or absence of a coolant. Burs and diamond instruments operated under any of these conditions leave scratched walls and margins which are undesirable if an accurate impression of the cavity is required. Fine grit sandpaper disks and fine grit carborundum stones create the smoothest surface, and so their use is recommended for the final finishing of occlusal and proximal walls.

OBSERVATIONS

Patient reaction to higher speeds is generally very favorable. Pain and unpleasantness are interrelated, and both are amplified by apprehension and time. The use of higher speeds for rotary instruments appreciably shortens the actual time of cavity preparation, and thus, the degree of unpleasantness or pain experienced by the patient is less.

It must be remembered that operations performed with very high speeds are still perceptible to the patient. Even though actual physical discomfort decreases at these speeds, it is possible that a patient's apprehension may increase. The dentist must be sensitive to the patient's tolerance of high speed and to his own ability to make the operation seem leisurely. The patient should be educated to the purpose and advantages of increased speeds; after this education has been accomplished, longer appointments combined with correct premedication will produce an extremely favorable situation in which to operate. It should be emphasized that the time saved by the use of high speed is in the preparation of the cavity and not in the other procedures that are necessary to complete the restoration. This factor may be overlooked by the individual who is striving to increase his production. The primary objective for the use of higher speed should be to produce a better quality of restorative dentistry. The latter goal can be achieved if the time saved in operating is used to improve the other steps necessary in the completion of the restoration.

Because much of the equipment appears familiar, there may be an initial tendency for the operator to think that the use of higher speeds differs little from the use of conventional speeds. The operator who has this conception may be disappointed with his first results and return to the conventional methods of cutting dental tissue. It requires time to become familiar with the characteristics of high speed rotary instruments, one of the reasons being that at the higher speeds there is a tendency to lose tactile discrimination. The speed at which this loss occurs will vary with different operators and is dependent to a

large degree upon experience. It has been stated very correctly by Dr. Sweet[13] that "if the speed is so great that any small perceptible pressure beyond the control of the operator will cause rapid cutting, then that speed is too great for safe operation." The dentist will find it helpful to practice on extracted teeth until he feels comfortable and confident of his ability. When beginning to use increased speeds on patients, a better transfer of the learning that has taken place in the laboratory will occur if simple cavities are selected. After a satisfactory technique has been developed, more complex cavities can be undertaken. It is essential that the dentist be able to visualize and have an excellent idea of the cavity preparation before beginning to operate. The correct chair position for the patient is also important because direct vision is often necessary. When developing a technique, the advantages of learning to work with a chairside assistant and an efficient aspirating unit should not be disregarded.

The use of ultra-high speeds, 100,000 rpm and above, is still in the experimental stages, as is the equipment for delivering these speeds. At the present time they must be considered a supplement or adjunct to regular operative practice. As was stated previously, increased speeds are not indicated for all operative procedures, and the ultra-high speeds are definitely limited in their application. At a certain level—and it will vary with each individual—high speed may cease to be an advantage and may actually become a disadvantage. It is possible that the use of ultra-high speeds, with their increased production, may cause the dentist too much mental and physical fatigue. Personal limitations should be recognized and honored.

There are many benefits to the patient and the dentist that can be gained from the thoughtful, cautious use of rotary instruments revolving at increased speeds. To obtain the fullest satisfaction and enjoyment from operative procedures each operator is encouraged to choose the speed, the equipment, and the technique that is most comfortable and effective *for him.* Not all operators will wish to operate with the ultra-high speeds.

SUMMARY

Vibration contributes to the discomfort usually associated with a dental operation. Many factors influence and cause the vibration that is perceived by the patient, but it is known that the major source of vibration is from the equipment and not the cutting instrument. One of the major advantages to the use of higher speeds for rotary instruments is that the intensity of the vibration is decreased as the frequency is increased. Speeds are available that make it possible to

increase the frequency of vibration beyond the threshold of perception by the patient.

Evidence has been collected, both clinically and in the laboratory, that demonstrates the necessity for using a coolant when speeds of 10,000 rpm or above are used. Air is not a desirable coolant because it fails to control the generation of heat, and it dehydrates exposed dentin. A sufficient volume of water or the air-water spray are the most effective coolants. Water, in copious quantities, is the coolant of choice if an efficient aspirating unit is employed.

Carbide burs are most effective for use with higher speeds than are steel burs. In dentin, the initial cutting rate of either carbide or steel burs is about the same, but the efficiency of the steel bur diminishes very rapidly. At the ultra-high speeds of 100,000 rpm and above, carbide burs cut enamel with ease; however, at the lower speeds they should be used primarily in dentin. Design is an important factor in the cutting effectiveness of a bur, and at the present time there is a great variation both in design and in efficiency amongst various manufacturers' products.

Diamond instruments offer conveniences in size and shape that are not afforded by carbide burs. Because of these conveniences diamond instruments are used almost exclusively by some operators even though their efficiency when cutting dentin is not as great as that of the carbide bur. Diamond points are most effectively used in enamel at light pressures and with an adequate amount of coolant. Instruments of inferior quality are a poor economic investment because their functional life at increased speeds of rotation is relatively short. All diamond instruments should not be operated at the same number of revolutions per minute, inasmuch as it is the peripheral speed that is important. A diamond point with a diameter of $\frac{3}{32}$ inch would have to travel three and one-third times as fast as a point with a diameter of $\frac{5}{16}$ inch in order to cut with the same efficiency. Clinically it is evident that the cutting rate of the smaller diamond instrument is increased tremendously at the ultra-high speeds; however, the cutting rate of opening wheels and other instruments of comparable or larger size appears to be increased only slightly at speeds in excess of 20,000 to 30,000 rpm.

As with any new technique, the use of higher speeds for rotary instruments is in a state of flux and transition. Despite all that has been learned about its use during the last five or six years, much investigation and research are still needed, particularly in connection with the use of speeds above 100,000 rpm.

The dentist who has not experienced the advantages to be gained by the judicious use of higher speeds of rotation is encouraged to

begin by first gaining experience with the technique in the laboratory. Thought should be given to the use of higher speeds only after becoming thoroughly familiar with the characteristics of cutting instruments that are rotating at 10 to 15,000 rpm.

There is now available a range of speeds from the conventional to 200,000 rpm. The choice of the highest speed to be used is one of individual concern. Its selection should be based upon sound biologic, physiologic and operative principles, and should offer the patient and the dentist confidence, efficiency and comfort.

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University of Michigan
School of Dentistry,
Ann Arbor, Michigan

High Speed Preparations

R. A. McEwen, D.D.S.

An important objective of the recent trend toward higher speed in rotary instruments has been the control of vibration. Modern anesthetics completely eliminate pain but have no effect on the transmission of bone-conducted vibrations. Walsh and Symmons[3] reported in 1949 that speeds of 6000 rpm produced the most uncomfortable sensation of vibration, while speeds above 60,000 rpm were above the human threshold of vibration perception.

New types of handpieces were developed with ball bearings, glass bearings and floating bearings to increase efficiency, control vibration and reduce the difficult problem of frictional heat within the handpiece. Resistance was removed from motors, transmissions of various types were developed, improved belts were fabricated, idler pulleys were improved, better water sprays were constructed and methods of removing water and debris rapidly from the operating area were introduced, all with one objective in mind: better preparations with less trauma and less vibration.

With these equipment changes, speeds of 20,000 to 30,000 rpm were available and proved beyond any question the inherent advantages to be gained. Clinical and microscopic studies verified the fact that higher speeds of rotary instruments were less traumatic to pulpal tissue than conventional speeds of 6000 rpm.

In order to achieve still further reduction of trauma and control of vibration, speeds were gradually increased above the 20,000 rpm level. With the conventional design of handpieces, particularly the contra-angle section, it was not practical to attempt treatment above 60,000 rpm. Several problems seemed to be insurmountable and contraindicated the great advancement in speed. One of the most difficult problems was frictional heat within the instrument itself, and it was recognized that gear-driven instruments would have to be discarded and a different method of motivation of power for the cutting tool would have to be introduced if speeds above the threshold of vibration perception (i.e., 60,000 rpm) were to be used. Also it was found necessary

to eliminate the metal-to-metal contact of the cutting tool to the chuck of the handpiece in order to cushion the vibrations inherent in any mechanical equipment.

Recognizing the advantages to be gained by the use of speeds above 60,000 rpm and realizing the impossibility of achieving this goal with conventionally designed handpieces, the idea of a completely new handpiece design was stimulated. The idea was originated by Dr. Richard Page, of Chappaqua, New York, who is responsible for much of the developmental work in this field.

As a result of this effort, a handpiece has been designed (Fig. 1) that produces speeds of over 100,000 rpm, that controls any vibratory

Fig. 1.

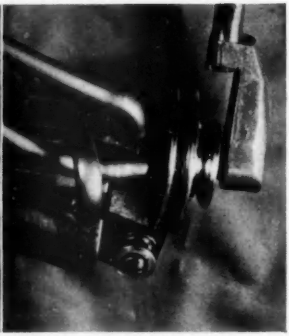


Fig. 2.

Fig. 1. Handpiece capable of developing 100,000 rpm.
Fig. 2. Belt drive of handpiece.

backlash from the drive unit, that does not heat and does not have to be lubricated.

The fact that this new contra-angle is belt driven (Fig. 2) eliminates the conventional gears and the necessity of lubrication and thus completely solves the heat problem. The cutting instrument itself is mounted in a rubber chuck. This type of chuck insulates the bur shank from any vibration that could originate within the driving mechanism.

SAFETY AND CONTROL

One of the first questions advanced is one of safety and control of a rotary instrument travelling at speeds of 60,000 to 150,000 rpm. Experience over the past year has shown that there is no problem of control of the instrument if this rule is followed: The speed of the rotary cutting tool depends on its size—the larger the size the

slower the speed. The range is from 60,000 rpm for a ⅝ inch disk to 150,000 rpm for a No. 2 or No. 701 carbide fissure bur. Only very light pressure is required to cut tooth structure; for the first time in dentistry the instruments are actually doing the work for which they were designed. The common occurrence of a bur running over a margin at low speeds never happens at 100,000 rpm. Every dentist has had a cutting instrument become engaged in a rubber dam and knows how, at low speeds, it will literally roll up the dam. This never happens at 100,000 rpm; owing to the design of the handpiece, the cutting tool either pulls out of the chuck or the engine belt starts to slip and no damage occurs. This is certainly an added safety factor. The author has purposely "pulled" instruments out of the chuck at 150,000 rpm to check the safety factor; the cutting tool immediately loses its torque and drops to the floor of the mouth.

CAVITY PREPARATIONS

The introduction of methods permitting treatment above the threshold of vibration perception has resulted in a completely new concept of cavity preparation. Owing to the high peripheral speed, the operator uses smaller instruments and very light pressure. There is no need of large, bulky instruments, either diamond or carbide, to facilitate rapid cutting, and as a result there can be much more finesse in both intra- and extracoronal preparations.[1]

Carbides cut enamel most efficiently above 100,000 rpm and actually plane rather than mill. At the present time the six-bladed instrument appears to be the most efficient.

Diamonds of proper grit and design also cut efficiently. A coarser grit with a wider distribution of the particles than was efficient at speeds of 20,000 rpm is necessary.

Carborundum instruments, particularly the wheel stones, are most useful and, in many instances, equal the cutting action of diamonds.

It is necessary to use water or water-air lubrication at all times, with the same application and equipment as used at lower speeds. Peyton[2] has been doing research on the control of temperature using coolants and reports that the temperature rise is no higher than at low speeds and is quite within the safety range.

To date, in the author's practice and from information from the various dentists who have been working at the 100,000 rpm-plus range for a period of a year, there has been a great reduction in hyperemic pulps. One pulpal death has been reported in a maxillary lateral but it was attributed to using heavy pressure and inadequate water lubrication.

This approach to cavity preparation using speeds above the threshold of vibration perception is particularly applicable in pedodontics. Added care is needed because the deciduous teeth are softer and the instruments cut very rapidly, but actually the control is so excellent that better preparations are a general rule.

Any instrument travelling at a high rate of speed develops considerable airborne noise, and a common question is, "Does it bother the patient?" The answer is "no." The patient is concerned with vibrations (bone-conducted noise, not airborne noise), and invariably patients, either adults or children, are much more relaxed than was common at conventional speeds.

The use of speeds in excess of 100,000 rpm has resulted in a new approach to cavity preparation. It is, therefore, necessary to re-evaluate our instrumentation and methods of approach to the different preparations.

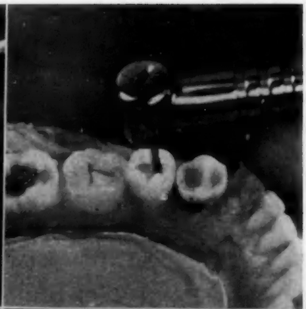
Class I Cavities

In class I preparations using carbides, the initial penetration is made with a No. 2 carbide bur (Fig. 3), using an oscillating motion. The second instrument is a No. 701 or No. 557 fissure bur (Fig. 4). Do not attempt to cut the full depth of a deep-seated cavity with the initial contact of the bur but, using a "planing" cut, reduce small layers of enamel until the desired depth is established. Using this approach, the operator has complete control of the depth of the cavity. This principle is advisable for all types of preparations.

It is not necessary to undercut with an inverted cone bur, as was the conventional approach. The suggested method is much less traumatic and the operator has the benefit of complete control. The axial wall outline form for either foil, inlay or amalgam preparations can be established by angling the head of the handpiece to establish either a taper, an undercut or a straight wall. The walls and floor of the preparation can be finished with a fine carborundum finishing stone. Carborundum instruments can be easily changed to the desired shape on a truing stone.

Using diamonds, for a class I preparation the initial opening is accomplished with a small wheel stone (Fig. 5) of proper size for the particular cavity. The thin wheel stones appear to be more satisfactory than the knife-edge type. After the initial penetration, a hollow core (Fig. 6) or torpedo-type diamond is used for the outline form and the preliminary finish is completed with a tapered cylinder diamond. The final finish is again done with the fine carborundum stone. While

Fig. 3. Fig. 4.



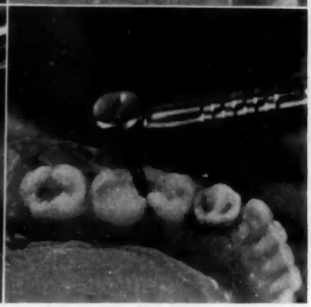


Fig. 5. Fig. 6.

Fig. 3. Initial penetration of class I preparation using a No. 2 carbide bur.

Fig. 4. Developing outline form of a class I preparation with a No. 701 carbide bur.

Fig. 5. Initial opening for an MOD preparation in molar using perforated wheel stone. Old amalgam has previously been removed from DO of second bicuspid, using a No. 6 round carbide bur.

Fig. 6. Development of outline form of multiple class II preparations using a hollow core. Initial opening made with perforated wheel stone.

diamonds cut effectively in all situations, the author prefers to use carbide instruments in class I preparations.

Class II Cavities

In class II preparations the same principle for initial penetration as used in class I preparations is the method of choice. In developing the proximal area, the cutting tool is moved bucco-lingually (Fig. 7), just medially to the marginal ridge, until the desired depth is established. Following this method, the remaining enamel will "flake" away and the approximating tooth will not be abraded. Again the desired preparation, for either foil, inlay or amalgam, can be developed by angling

the head of the handpiece. Using carbides, the step area is established, in most instances with a No. 701 tapered fissure bur. With diamonds, a small hollow core or tapered cylinder instrument is used. In bicuspids the carbides are the instrument of choice for all class II preparations. In molars in which caries is not extensive, again carbides would be preferred.

In multiple class II preparations, diamonds are more satisfactory. The initial opening is accomplished with a diamond wheel stone, the outline form with a torpedo or hollow core, the preliminary finish with

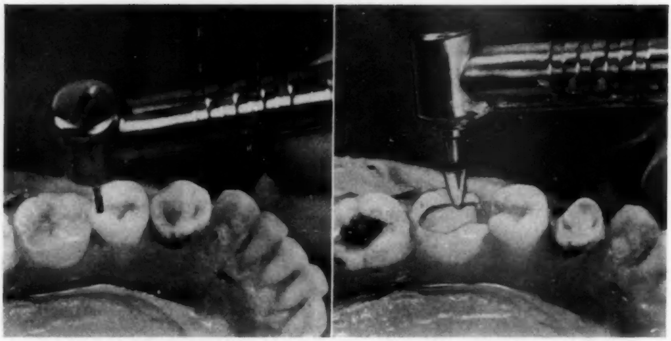


Fig. 7. Fig. 8.

Fig. 7. Developing the proximal step area in a class II preparation using a No. 701 carbide bur.

Fig. 8. Finishing cavosurface bevel for a class II inlay preparation using a fine carborundum finishing stone.

a tapered cylinder and the final finish with a carborundum finishing stone (Fig. 8).

It is not the intention to suggest that hand instruments are not necessary, but their role has a lesser place in the armamentarium. It is advisable always to check the gingival floor with marginal trimmers and, of course, to use chisels, hoes, etc. as is necessary for the particular situation.

One of the most difficult class II preparations is an MO in a mandibular first bicuspid. It is often necessary to angle the pulpal floor to maintain sufficient strength in the lingual wall. With this new instrument it becomes comparatively simple to accomplish a perfect cavity design in this area.

Class III Cavities

At the present time small class III preparations are not possible at 100,000 rpm, since very small cutting tools are not available. The

smallest round bur is a No. 2, which is too large in many instances where only incipient caries is present. Neither is it practical for invisible foil preparations. In the larger class III preparations the labial wall is established first, parallel with the enamel rods, using a chisel if necessary and then planing the wall with a No. 701 carbide or very small tapered-cylinder diamond. The internal area of the cavity preparation is developed with a No. 2 carbide bur. The final finish of the walls is completed with hand instruments and fine carborundums. The provision of retention points for foil preparations follows the conventional pattern with hand instruments.

Class IV Cavities

In class IV preparations the first step is to establish the proximal wall using a ⅝ inch diamond disk. Disks are rotated at approximately

Fig. 9. Class V preparation outline form using a No. 701 carbide fissure bur.

60,000 rpm. The remainder of the cavity preparation can be completed with a No. 701 or No. 557 carbide bur, or again a small tapered-cylinder diamond. By angling the handpiece the necessary cavosurface bevel can be developed and finished with a small carborundum instrument.

Class V Cavities

Class V preparations are prepared using only a No. 701 carbide bur (Fig. 9), planing gradually to the desired depth. The preliminary finish can be completed using this one instrument.

Removal of Deep Caries, Old Amalgam and Inlays

Where it is necessary to remove deep-seated caries, the method of choice is to use a No. 6 carbide bur rotating at approximately 80,000

rpm, gently and intermittently touching the designated area. This will remove all caries and the operator has perfect control of the situation.

In removing old amalgams the No. 6 carbide bur is the most efficient instrument, again working with an oscillating motion. It may be necessary in some step areas to use a fissure bur, but the general instrument is the No. 6.

In removing inlays the most practical procedure is to cut through the occlusal section with a diamond wheel stone. If the inlay is small and there is a possibility of striking the occluso-buccal-lingual walls with the wheel stone, the No. 6 carbide bur can be used. The author prefers, wherever possible, to make at least the initial cut with a diamond.

CROWN, JACKET AND VENEER PREPARATIONS

Crown Preparations

For three-quarter and full coverage preparations on posterior teeth, the occlusal reduction is accomplished with a small diamond (Fig. 10) or carborundum wheel stone (Fig. 11), not to exceed 5 mm. in diameter. The speed of the instrument should be approximately 70,000 rpm (slightly faster than used for disks), and it appears to be better to use a pushing motion rather than the conventional pulling motion. Since these types of instruments have a comparatively larger area in contact with the tooth than do conventional instruments, it is advisable to use an auxiliary source of water to lubricate the tooth.

Proximal cuts are made with the ⅝ inch diameter saws (Figs. 12 and 13) and disks (Figs. 14 and 15). Most operators are accustomed to using large disks in a straight handpiece for this particular reduction and the smaller size will at first appear awkward, but the difficulty of access is quickly overcome. Often the cup-shaped saw and disk can be used both mesially and distally.

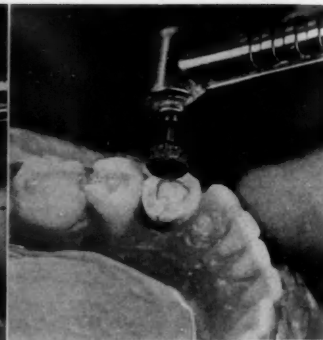
Buccal and lingual reduction is done either with a No. 701 or No. 702 carbide bur (Fig. 16) or with a tapered-cylinder diamond (Fig. 17) not to exceed 2 mm. in diameter. These instruments, either carbide or diamond, can be operated at 125,000 to 150,000 rpm.

Owing to the short length of the flutes on a carbide, it is necessary to reduce the walls step by step. This is actually an advantage, as the exact amount of reduction is known at all times. Again the method of reduction is by planing.

If the gingival finish is a feather edge, a conventionally shaped

Fig. 10.

Fig. 11.



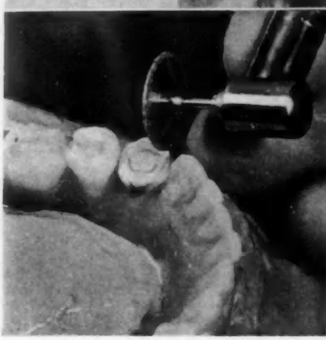


Fig. 12.

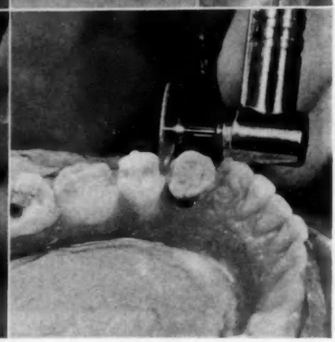


Fig. 13.

Fig. 10. Occlusal reduction for full coverage or three-quarter crown preparation using a 5 mm. diamond wheel stone.

Fig. 11. Occlusal reduction for full coverage or three-quarter crown preparation using 5 mm. carborundum stone.

Fig. 12. Cup-shaped saw used to cut through the mesial contact area on a posterior crown preparation.

Fig. 13. Cup-shaped saw used to cut through the distal contact area on a posterior crown preparation.

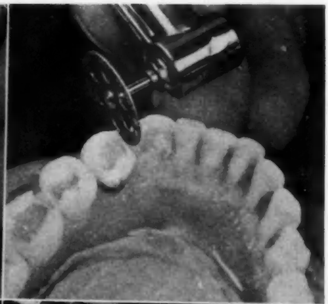
diamond flame stone may be used. The author prefers a very small straight-cylinder diamond for this area. If a chamfer is desired, a diamond is available for the handpiece that will develop the desired angle. If the gingival finish is to be a shoulder, the carbide fissure bur, either No. 701 or No. 557, is the instrument of choice.

Jacket or Veneer Preparations

For jacket or veneer preparations the incisal reduction is accomplished with a 5 mm. wheel stone, either diamond or carborundum.

Fig. 14.

Fig. 15.



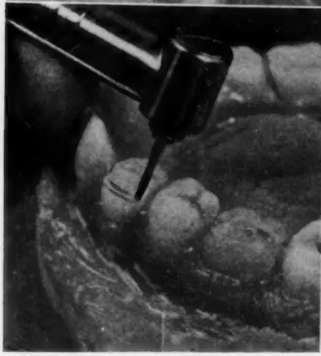


Fig. 16.

Fig. 17.

Fig. 14. Cup-shaped disk establishing distal taper on a full crown preparation.

Fig. 15. Perforated outside-cut disk used on mesial surface of bicuspid full crown preparation.

Fig. 16. Buccal reduction of a veneer preparation on a bicuspid using a No. 701 carbide fissure bur.

Fig. 17. Buccal reduction for veneer crown using a hollow core instrument. Approximately one-half of buccal surface completed in first step. Same application with tapered cylinder diamonds.

Proximal walls are reduced with the ⅝ inch disks, inside and outside cut. Labial and lingual walls are reduced with either a No. 701 carbide or small tapered-cylinder diamonds. The shoulder area can be outlined as to depth and position by a special diamond shoulder instrument and completed with a fissure carbide. Because of the excellent control of the instrument, the shoulder can be completed below the gingival crest without soft tissue laceration; this was a difficult step before the era of high speed. The preparation is finished with a fine carborundum finishing stone (Figs. 18 and 19).

Fig. 18.

Fig. 19.

Fig. 18. Final finishing of a veneer crown preparation using a fine carborundum stone.

Fig. 19. Use of the truing stone for carborundum instruments.

INSTRUMENT LIST

The list of instruments applicable to this new principle is as follows:

Carbides

Round, Nos. 2, 4, 6
Tapered fissure, Nos. 701, 702
Straight fissure, Nos. 557, 558
(The No. 1 round bur and the No. 700 fissure bur in tungsten carbide will soon be available)

Carborundum Instruments, Regular and Finishing

Wheel stone
Tapered cylinder
Straight cylinder
Cone shaped

Diamonds, Operative Instruments

Small thin wheel stones
Small cylinders, tapered and straight
Hollow core
Torpedoes

Extracoronal Instruments

Wheel stones, 5 mm.
Saws, straight and conical, ⅝ inch
Disks, straight and conical, ⅝ inch
Cylinders, tapered and straight, various sizes: maximum 2 mm.
Flame stone
Chamfer stone

SUMMARY

Using speeds of 100,000 rpm and observing the necessary changes in the use of cutting tools has resulted in better preparations. This

technique has the further advantage of increased control of trauma and the non-occurrence of hyperemic pulps. Patients are no longer apprehensive, since treatment is completed above the threshold of vibration perception. This modern technique presents a new era in dental treatment.

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1293 Peachtree Street
Atlanta, Georgia

The Present Status of Airbrasive and Ultrasonic Equipment

HARRY H. POSTLE, D.D.S.,

AND

WILLIAM LEFKOWITZ, D.D.S.

AIRBRASIVE EQUIPMENT

The airbrasive technique has been available to the dental profession for only six years. Although the instrument is not universally popular, many dentists, after developing the necessary skill and gaining adequate experience, have become extremely enthusiastic about this new method for cavity preparation. No one instrument or technique is universally ideal for cavity preparation, and airbrasive is no exception. Unfortunately, dentists who have become skilled in the use of rotary instruments expect to be able to use the airbrasive technique with equal or better results without training and experience. Before the instrument is evaluated by an individual dentist, he should consider the possible causes of difficulties. First, failure to use airbrasive successfully may be due to the lack of a thorough understanding of the instrument and its intended uses; second, the technique, while not difficult, is entirely foreign to methods we have used for years; and third, proper teaching facilities generally have not been available.

To gain skill and confidence with airbrasive one must not only thoroughly understand the workings of the unit but must also be well grounded in the technique for cavity preparation. There is no single universal instrument capable of satisfactorily preparing every class of cavity. It is of utmost importance that the operator thoroughly understand the indications and contra-indications for airbrasive. Many dentists have been led to believe erroneously that this technique would almost entirely replace rotary instruments, an unfortunate misunder-

From the Department of Operative Dentistry, The Ohio State University College of Dentistry, Columbus.

standing which has led to much confusion. At present rotary tools remain basic cutting instruments. As modern science develops new instruments one can expect dramatic changes for certain types of cavity preparations or for certain steps in cavity preparation. At present, complete replacement of rotary instruments is not at hand. There is no reason to expect any of these new instruments to perform all duties in operative dentistry. Now, and even more so in the future, it will be necessary for dentists to avail themselves of a variety of instruments in order to give their patients the best service modern dentistry can provide. Too many dentists have rejected the airbrasive technique without ever realizing its great potential.

Description of Unit

The Airdent unit is a well designed, neat, compact, and professional-appearing piece of equipment (Fig. 1). Its major parts consist of a mobile cabinet which houses all working parts of the unit; two cylinders in the back of the unit, containing liquid carbon dioxide to provide the propelling energy; and mixing chambers, one containing cutting powder (aluminum oxide) and the other cleaning powder (dolomite), in the top of the cabinet. These mixing chambers are mounted on individual vibrators. The foot switch activates the vibrators and opens pinch valves controlled by solenoid switches, allowing the abrasive to be sifted from the chambers into the carbon dioxide stream. The abrasive stream is then carried through rubber tubing to the handpiece and through the tiny nozzle tip (Fig. 2). When leaving the tip, the particles are traveling at an extremely high velocity, in excess of 1500 feet per second, in a precise, narrow cutting stream. Gauges and dials on the face of the cabinet allow the operator to select the abrasive of choice and regulate the desired richness of the mixture. A recovery system (Fig. 1) including a suction hood, supported by a mechanical arm with accessory operating light and dust pan, collects the spent abrasive.

The handpiece (Fig. 2) is very light, resembling a fountain pen in size and weight. It consists of a handle, a shaft, and a nozzle tip. The shaft is attached to the handle by means of a ball and socket joint that provides excellent mobility of the working tip. This tip is made of sintered tungsten carbide, which provides a working point free from excessive wear. Tips are available with round and rectangular orifices and in straight and right angle form. The right angle tip with a round orifice (0.018 inch diameter) is most commonly used.

The airbrasive technique brings to the dental profession an entirely new concept of using energy for the removal of hard tooth structure.

Fig. 1.

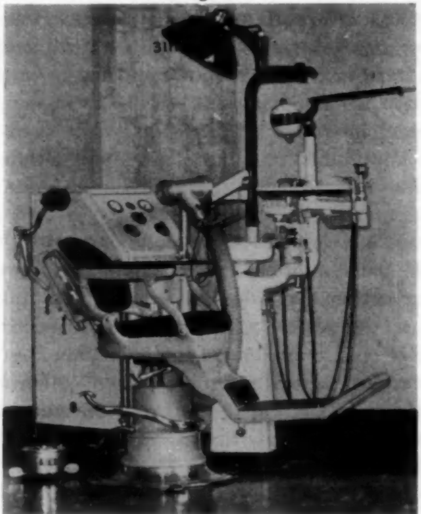

Fig. 2.

Fig. 1. Special techniques room, College of Dentistry, The Ohio State University. Airbrasive unit in operating position at chair.

Fig. 2. Airbrasive handpiece. Note the size in relation to hand of operator and the light pen grasp used.

The technique differs radically in that it converts the potential energy of a compressed gas into kinetic energy and charges abrasive particles with this energy. This method rapidly and efficiently removes sound tooth structure while eliminating many of the inherent difficulties associated with rotary instruments, such as heat, pressure, vibration and bone-conducted noises.

Indications, Contraindications and Critique

Cavity Preparation. The airbrasive technique has many advantages over rotary instruments. One must keep in mind that airbrasive was

invented and developed for the sole purpose of making dental operations a more pleasant experience for both patients and dentists. Airbrasive will not improve upon the quality of the preparations made with present rotary instruments. However, one need not make an inferior preparation. In difficult cases, the final finishing may be done with conventional instruments. There are many uses for this instrument, but it is important to realize that a combination of instruments, using each where indicated, is absolutely essential for good operative dentistry.

Patient response to airbrasive technique is overwhelmingly in favor of its use. While pain is not completely eliminated, the average patient will prefer preparations by airbrasive without local anesthesia. Under these conditions, the patient will usually experience some pain, described as that of cold air striking a tooth, but not so severe as to need anesthesia. Of course, individual thresholds of pain vary greatly, and there should be no hesitation to use local anesthetics in association with this technique when a particular situation calls for its use.

Airbrasive is one of the fastest methods for removing tooth structure, and thus fulfills the desire of both the dentist and the patient for speed in completing the preparation.

The advantages of airbrasive are not for the patient alone. When the operator gains confidence and skill in handling the instrument, it readily offers many advantages to him. The instrument is very relaxing to use. The operator develops the feeling that the work is being done for him. He merely guides the instruments and watches the tooth structure disappear. Speed is increased, not only because the tooth structure is actually cut very rapidly but also because there is usually no waiting for anesthesia. It is also much easier to make preparations in various quadrants of the mouth without leaving patients undesirably anesthetized for several hours. Thus more work can be done per sitting, which increases the output.

Airbrasive is at its best when cutting hard, sound tooth structure where good access is available. Because of the nature of its cutting characteristics, it is most adaptable to intracoronal preparations. These facts indicate that the greatest use of airbrasive is to be found in the preparation of cavity classes I, II, III, IV, and V. With extreme skill, it is possible to make three-quarter crown preparations, full crown preparations and jacket crown preparations, but since the high speed technique produces maximal efficiency and excellent results for extracoronal preparations, airbrasive technique offers little advantage here.

The accuracy of the instrument, while not equaling that of conventional instruments, depends upon the operator's skill. It was not intended to provide precise cutting. When the operator develops the

proper skill and technique, he should at least be able to remove all the hard tooth structure and have a well formed, roughed-out cavity preparation. These preparations can be finished with very little effort and time with hand or rotary instruments.

Removal of Old Restorations. Airbrasive is also at its best when working on teeth with virgin cavities, because it cuts sound tooth structure more readily than carious material. Removing amalgam or gold inlays presents a problem. The abrasive will cut amalgam, but somewhat slower than it cuts tooth structure. If the amalgam to be removed is small, it causes little inconvenience. It is more practical to remove large amalgams in the conventional manner. It is almost impossible to cut gold with the airbrasive stream. If the preparation can be enlarged, inlays can be easily removed by cutting around their outlines.

Another excellent use of the instrument is for removing old silicate fillings in need of replacement. The cleaning powder ($CaMgCO_3$) will remove silicate but not the tooth structure. This technique is fast and painless, and eliminates the danger of enlarging the cavity size. During prophylaxis, silicate restorations must be protected. Other desirable uses for airbrasive include opening the pulp chamber for root canal drainage, removing cement from inlays and facings, and removing porcelain crowns.

Prophylaxis. Airbrasive is indicated for limited use in prophylaxis. Careful investigators[1,20] have demonstrated increased enamel loss, microscopic pitting, and luster loss following the use of this instrument. Although these faults limit the use of airbrasive for routine prophylaxis, they can be minimized by the proper and careful use of the instrument followed by polishing of the cleaned surfaces with a rubber cup and fine pumice or silex. This technique restores the luster and surface smoothness of the enamel. The slight increase in enamel loss seems insignificant if repeated use for the same patient is avoided. Obviously it is advisable to limit the use of airbrasive in prophylaxis to heavily stained teeth where it is difficult to obtain desirable results with conventional methods. With the dolomite abrasive stream at a lowered pressure (40 lbs. per square inch), stubborn stains are readily removed from pits, fissures, grooves, and interproximal spaces. In these cases subgingival scaling is first completed with hand instruments and airbrasive is then used for the removal of heavy stains and deposits on the crown of the teeth. The surfaces should then be polished as mentioned above. By correctly using the airbrasive instrument as an adjunct to our present equipment it is possible to give our patients a superior prophylactic service with less effort and strain on the part of the dentist.

Problems of Access and Vision. The need for good access and vision while operating has been a disadvantage and also a factor limiting the use of airbrasive. This technique requires hand and eye coordination. What one sees with the eye guides his hand—there is no sense of touch. Where good access and vision are not possible, the technique cannot be used.

Working by indirect vision has been a continual source of difficulty. Mirrors will frost when in contact with the abrasive rebound. At present, the mirror is protected with a plastic coating or cellulose tape, but it still does not provide adequate vision. For this reason, every effort should be made to use direct vision wherever possible. Elevating and tilting the patient back for direct vision eliminates the problem in the upper arch as far distally as the first molars and sometimes second molars. Although use of the airbrasive technique with indirect vision is possible, it presents so many problems that it has been discarded by many operators as impractical.

The Problem of Dust. The dust or abrasive rebound has been a continual problem. The recovery apparatus is good but not as efficient as desired. When the suction hood is held in its proper position and the abrasive stream is directed at the proper angle, one has very little trouble with recovery. It may be regarded as a nuisance problem similar to that encountered with water coolants when using the washed field technique. Quantities of dust have not been found to settle throughout the operating room.

Inhalation of Al_2O_3 and $CaMgCO_3$ has concerned the profession since the development of the airbrasive technique. Both of these powders are inert, non-toxic abrasives of an average particle size (28 microns) that is effectively filtered out by the human breathing apparatus. Investigators[8,12,19] have been active in this field. Some respiratory irritations have been produced in experimental animals by forcing them to inhale extremely large quantities of these abrasives. However, there has been no experimental evidence that the inhalation of small amounts, comparable to that which might be expected when using airbrasive, could be a serious health hazard to the patient or dentist. This technique has been in use six years, and no health impairments have been reported from its users. There is no free silica in either abrasive, and thus no hazard of silicosis.

The Rubber Dam. Many operators believe that superior work can be done in almost all phases of operative dentistry by using a rubber dam, and this certainly holds true for the airbrasive technic. However, the rubber dam is certainly no more essential than when using other types of cutting instruments. By using a rubber dam the operator is able to maintain a dry field with good vision and access to the tooth,

and spent abrasives are kept from accumulating in the patient's mouth. Because the abrasive stream cuts rapidly, a dry field is required for only a short length of time; therefore, isolating with cotton rolls will accomplish the desired results if the dentist prefers not to use the rubber dam.

Pulp Safety. Unpublished findings at Ohio State University and other laboratories have established that the airbrasive technique of cavity preparation is safe and does not cause irreversible pulp injury.[17] Airbrasive certainly provides a technique which is less traumatic to the tissues surrounding the tooth, since pressure and vibration are practically eliminated.

Cost, Size and Future Possibilities. Dentists have objected to the cost and size of the Airdent unit.[16] A smaller instrument, possibly attached to present equipment, at a reduced cost, certainly would gain more popularity.[4] Even so, the present equipment, after initial expenses, offers a technique no more costly than our conventional methods using diamond points and burs. Maintenance and operating costs of the unit are small.

It is to be expected that some changes may be made in the Airdent unit. The inventor, Dr. Robert Black, points out in a recent article[4] some future possibilities. Some of the suggested ideas were (1) smaller, more compact units, possibly incorporated in our present dental unit; (2) a less costly unit; (3) a synthetic sapphire mirror to prevent mirror frosting.

Technique of Use

It is not the purpose of this article to present a detailed description of techniques for the use of the airbrasive instrument. The following paragraphs present a brief discussion of its uses for the classes of intracoronal preparation. A mesio-occlusal amalgam preparation will be described in detail.

There is no substitute for experience when this technique is used. The operator must know the ideal places for its use as well as its contraindications. Many dentists have become discouraged while trying to do preparations which are actually impossible to do with the instrument. Airbrasive has many uses without making it a universal instrument.

The class I preparation presents an ideal situation for the use of airbrasive. Access and vision are usually good and the operator finds it very easy to extend through pits and fissures. The technique is similar to that used to make the occlusal portion of a class II cavity (Fig 3*A* and *B*).

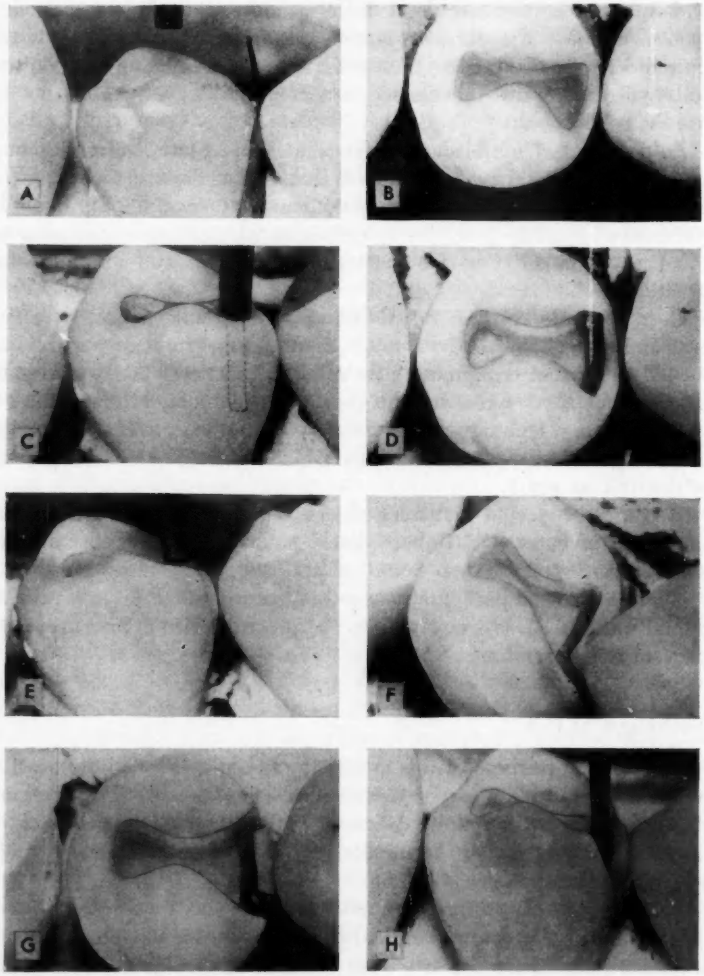

Fig. 3.

Fig. 3. *A*, Stainless steel matrix in place; note nozzle tip relationship to tooth. *B*, Occlusal portion completed. Note widened mesial area and thin layer of marginal ridge still remaining. *C*, Nozzle tip distance for cutting axial slot. Dotted lines represent position and depth of slot. *D*, Axial slot completed. Note extension to self-cleansing areas. *E*, Position of nozzle tip for making buccal proximal line cut. *F*, Completed buccal proximal line cut. *G*, Proximal section isolated. *H*, Fracturing isolated proximal section with hand instrument. *I*, Roughed out airbrasive cavity preparation. *J*, Sharpening line and point angles. Note nozzle tip pointing directly at line angles. Also note 1 mm. nozzle tip distance. *K*, Preparation fol-

For class II preparations this instrument is very useful because interproximal cavities require the removal of much sound tooth structure. Details of technique will be described below.

In class III cavities, airbrasive can also be put to good use. As mentioned before, the instrument can readily be used for removing old silicate restorations. The abrasive stream will not cut acrylics. New proximal class III cavities are also easily prepared. The labial or lingual outline form can be cut in a matter of seconds, making access for the spoon excavator to remove soft decayed material. Retention form is then easily made with the cutting stream.

Class IV cavities may be roughed out with the airbrasive instrument. However, the frequent presence of old restorations in these

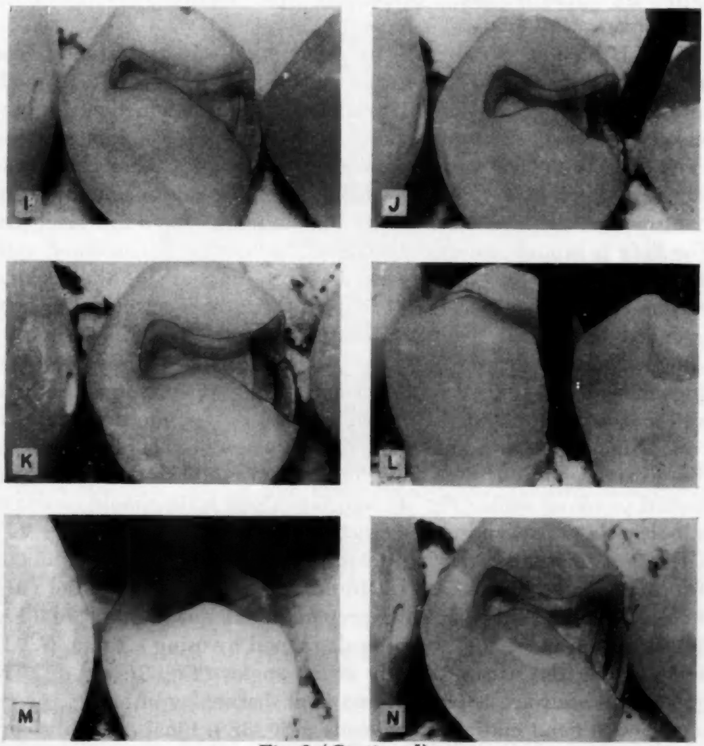

Fig. 3 (*Continued*).

lowing completion of airbrasive procedures. Note proximal retention form. *L,* Use of hand cutting instruments for gingival cavosurface bevel and sharpening line angles. *M,* Use of fissure bur for final sharpening of occlusal portion. *N,* Completed cavity preparation.

cavities decreases the usefulness of the instrument. Great precision, which airbrasive does not offer, is also essential for this restoration. For these reasons the instrument is of limited use for class IV preparations.

Class V preparations vary in their suitability for the use of airbrasive. Small cavities just above the free margin of the gingiva can easily and rapidly be prepared by airbrasive. Larger cavities extending beneath the gingiva present a greater problem owing to hemorrhage and relative inaccessibility, and therefore are more readily prepared with conventional instruments. This region of the tooth is cut rapidly with the abrasive stream and therefore precise control is difficult.

Class II Preparations. Several investigators[2,3,14] have outlined techniques for airbrasive cavity preparation. The following description includes many of their ideas.

Class II mesio-occlusal amalgam preparations (Fig. 3) are ideal for the use of airbrasive. The operator should first isolate the tooth with cotton rolls or rubber dam. The adjacent tooth should then be protected by placing a stainless steel matrix through the contact area (Fig. 3*A*). With a nozzle tip distance of 2 to 4 mm., the occlusal portion is first prepared (Fig. 3*B*). Keeping the stream in slow but constant motion, the high areas within the outline form are first removed. The floor is brought to a common level and cutting is continued until the proper depth has been reached. On the mesial side the occlusal portion should be widened to bring walls to self-cleansing areas, and extended halfway through the marginal ridge (Fig. 3*B*). Next, by using a 1 mm. N.T.D. (Fig. 3*C*), a slot is cut between the buccal and lingual walls (Fig. 3*C* and *D*). This slot or line cut forms the axial wall and establishes the depth and gingival wall of the proximal portion. Using 1 mm. N.T.D. (Fig. 3*E*), the operator should now isolate the proximal portion by making line cuts to establish the buccal and lingual proximal walls (Fig. 3*F* and *G*). These walls should be cut in self-cleansing areas and to the exact depth of the axial slot (Fig. 3*G*). The use of a No. 6 exploring point will aid in measuring this depth. The proximal section is next fractured away with a hand chisel (Fig. 3*H*). A roughed-out airbrasive preparation is now completed (Fig. 3*I*). Line and point angles can be sharpened by using a 1 mm. N.T.D. and pointing the stream directly at the angles (Fig. 3*J* and *K*). The gingival cavosurface is beveled and final sharpening of angles is completed with hand cutting instruments (Fig. 3*L*). Final occlusal sharpening is accomplished with a fissure bur (Fig. 3*M*). When this technique is followed carefully, the final cavity preparation (Fig. 3*N*) should differ in no respect from that done with conventional instruments.

Converting the above technique to that needed for a class II inlay preparation is not difficult. By changing the nozzle tip angulation the walls of the preparation can be made to diverge slightly toward the occlusal. Final finishing is accomplished by using hand cutting instruments, sandpaper disks, and a diamond point.

Summary

The airbrasive technique, while not widely accepted by the dental profession, offers rewarding advantages for selected cases. Its virtues should not be lost to the profession through misunderstanding. The instrument is limited in use, yet is adaptable to many routine operative procedures.

Fig. 4. Special techniques room, College of Dentistry, The Ohio State University. Ultrasonic unit in operating position at chair.

ULTRASONIC EQUIPMENT

Description of Unit

The ultrasonic dental unit is compact and convenient (Fig. 4). Its professional appearance meets the standards of modern equipment. It consists of an ultrasonic generator and a magnetostrictive transducer which is within the handpiece. The generator delivers electrical

energy to the transducer, which creates the vibrations used to remove hard substances. A water cooling system is incorporated into the equipment to control the heat generated in the handpiece. Another system directs a water-borne abrasive or slurry against the working point and provides an additional water jet for irrigating the cavity. A foot control operates the entire apparatus.

The energy used for removal of enamel and dentin is generated in the handpiece (Fig. 5). The electric current causes the transducer of the handpiece to contract and expand slightly. This action, expressed as amplitude, is determined by the number of watts conducted to the handpiece and may be regulated by a dial. The desirable amplitude depends on the length and thickness of the working point. Long, thin shanks do not tolerate a large amplitude and may fracture. Working points used for removal of enamel and dentin are constructed to utilize greater amplitudes. The purpose of the power adjustment is to attain the maximal amplitudes in harmony with the tolerance of the instrument.

Every transducer has its own optimal frequency (number of vibrations per second). To obtain the desirable frequency, an oscillator regulates the frequency of current to the transducer. This is called "tuning," which is the act of regulating the frequency of the oscillator so that it is in tune with the natural frequency of the transducer. In making the adjustment, it is possible to hear a characteristic hissing sound arising from the water cooling system in the handpiece. Frequency is a function of the shape, composition, and size of the total vibrating system—in this case, the transducer plus the working point. Therefore, each change of instrument requires an adjustment for correct tuning.

The handpiece, $7\frac{15}{16}$ inches long, $\frac{11}{32}$ inch in diameter and $9\frac{1}{2}$ ounces in weight, is convenient for most dental operations (Fig. 5). The functioning end is threaded to receive working points which are securely screwed into place with a small wrench. In operation, the handpiece vibrates in the range of 29,000 times per second. The thrust of the working point is about 0.0016 inch. The vibrations are not perceptable to the operator while holding the handpiece. An abrasive slurry of aluminum oxide and water is conducted to the vibrating point to enable it to remove enamel and dentin. The working points are monangle instruments in the form of cylinders, hatchets, hoes or inverted cones (Fig. 6) which enable the operator to establish almost all classic cavity forms. For all practical purposes, it may be called a vibrating instrument.

The most significant factor in removal of enamel and dentin is a phenomenon known as cavitation which may be defined as the forma-

tion of local cavities in a liquid as a result of reduction of total pressure. It occurs when the pressure of a liquid on the rapidly vibrating instrument is reduced so low that the flow of the liquid cannot follow the surface of the instrument, causing either a vacuum or a region saturated with the vapor of the liquid. Air or impurities in the liquid act as nuceli which encourage the formation of cavitation bubbles. Collapse of the bubble imparts a high acceleration to particles in the

Fig. 5.

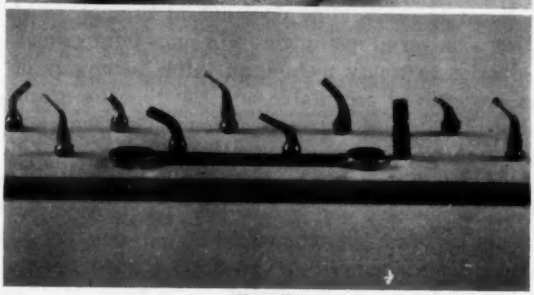

Fig. 6.

Fig. 5. Ultrasonic handpiece. Note size in relation to hand of operator. Arrow points to tubing which conducts water and slurry to working point.

Fig. 6. Working points mounted in block.

immediate vicinity of the bubble. Theoretically, the action of cavitation prepares the surface by freeing weakly bonded particles and it accelerates abrasive particles on the surface of the bubble to further weaken particle bonds and thus erode the surface. Regardless of its modus operandi, the mechanism can and does remove enamel and dentin efficiently.

General Characteristics

The vibrating working point is most efficient when the operating load is minimal. The removal of enamel and dentin occurs practically

without physical contact of the instrument and the tooth. Despite the lack of pressure, the operator retains the tactile sense so desirable in operative procedures. Operating under heavier than optimal load produces undesirable results: cavitation is markedly reduced. The energy, instead of being localized, is transmitted directly into the tooth by close coupling, and excessive temperature rise occurs. Fortunately, an excessive load is accompanied by a characteristic noise, easily detected by the operator.

The most efficient removal of tooth tissue occurs when the nib or face of the instrument is vibrated directly into the tooth in a thrusting motion. For extending cavities, planing walls and beveling margins, the side of the working point is used.

The vibrating working point used for cavity preparation is incapable of removing soft carious dentin. Ultrasonic spoons adapted for this use are available. The instrument will not cut gold effectively, but will cut amalgam as precisely as it does dentin. The clinical appearance of enamel and dentin planed by an ultrasonic working point is smooth and well finished.

Ultrasonic cavity preparation does not, at present, satisfy the age-old quest for a universal instrument. For most intracoronal operations it is far superior to rotary techniques. After two years of use,[17] the instrument has proved acceptable and the time for studies of technique and working point design is at hand. One may anticipate improvements in these areas.

From the point of view of classic cavity preparation, the ultrasonic method has one outstanding virtue: the precisely shaped working points produce an accurately controlled preparation. Parallel or tapering walls are determined by the precision shaped instruments. Flat pulpal and curved axial walls present no problem. Well defined line and point angles, flat or curved smooth walls and well finished surfaces are easily attained by ultrasonics.

Ultrasonics is capable of preparing every class of cavity for any restorative material. Changing instruments is time consuming; if ultrasonics is used in cooperation with hand instruments, the efficiency is increased. The use of spoon excavators and chisels facilitates most operations.

The best results are obtained when direct vision is possible. Lingual surfaces of upper anteriors and most surfaces of upper molars present a problem. The slurry impairs vision unless an aspirator is used, and the saliva ejector alone is inadequate. During cavity preparation, the water jet is used at intervals to irrigate the area. The rate of ultrasonic cutting is satisfactory, but the ultrasonic instrument does not reduce chair time for the average practitioner.

Advantages and Disadvantages

A survey of clinical experiences by 161 general practitioners[13] has shed light on the effectiveness of the ultrasonic instrument. Since the instrument has become part of their office equipment, only 13 per cent of all intracoronal preparations were made with rotary and hand instruments. Most intracoronal preparations were made with the ultrasonic instrument alone; less than half of the preparations were made with ultrasonic technique in combination with rotary or hand instruments. For extracoronal preparations such as full, shoulder or three-quarter crowns, a slightly larger percentage of operators used rotary instruments. It was also significant that the longer the operator used the ultrasonic unit, the less he required rotary or hand instruments, indicating that the development of technique is an important factor in the use of the instrument.

Ultrasonic technique enables the operator to prepare a cavity as well as, if not better than, with conventional methods. The problem of mechanical retention appears to have been eliminated with newly designed working points. In considering all classes of intracoronal cavities, only the small proximal class III preparations present the problem of excessive sacrifice of enamel and dentin.

Use with Other Instruments. The first clinical usage of ultrasonics was predicated on the assumption that a complete cavity preparation could be made without the use of hand or rotary instruments. This is possible, and the development of skills and working points may bring this hope to reality. In its present stage of development, certain operations may be more efficiently completed if hand or rotary instruments are combined with ultrasonics. Those operations which may be concluded in a minimum of time, i.e., less time than it takes to change ultrasonic working points, should, in the interests of efficiency, be completed with hand or rotary instruments. The gingival bevel quickly and satisfactorily done by a marginal trimmer may be used as an example. Another illustration is the removal of carious dentin with an ultrasonic spoon excavator. To adapt a spoon and retune the instrument takes longer than the entire operation completed with a hand instrument. In general, the ultrasonic instrument can complete all preparations fully, but greater efficiency is achieved by relegating some short operations to hand or rotary instruments. This is not an objectionable feature but simply a logical procedure.

Operating Cost. During cavity preparation the steel working points abrade and lose their definition. After an average of 11 minutes of use, it is necessary to reshape the working point; this may be done at the

chair with a mounted stone. The life span of a working point is about 33 minutes. As yet no studies have been made of the cost of cavity preparation with different instruments. The efficient life span of a steel bur has been studied[10] and, from clinical experience, the cost of ultrasonic cavity preparation compares favorably with that using rotary instruments.

Patient Reaction. Ultrasonic preparation of teeth is a more tolerable procedure than rotary technique. About 35 per cent of 27,257 patients reported painful experience during cavity preparation with ultrasonic technique. Of these, only 21 per cent received local anesthetics. The same operators preparing cavities with rotary instruments used local anesthetics in 75 per cent of 16,156 patients during the same period. Other experiences, bordering on unpleasant sensations, were of no consequence. It may be said that temperature rise, vibration, noise and pressure are practically non-existent. Approximately 90 per cent of the patients are more relaxed and prefer ultrasonics to rotary instruments. The operator experiences less fatigue preparing cavities with the ultrasonic unit.

Pulpal Response. Several laboratory experiments were designed to test the pulpal response to ultrasonic vibrations. One investigation, on the continuously erupting incisors of guinea pigs, reported certain injurious results in the developing portion of the tooth.[9] This was followed by seven oral and published reports on experiments on teeth of human beings, monkeys and dogs.[5,7,11,15,18,19,22] All were in agreement that the pulpal response to ultrasonic technique is the same as that found after the proper use of rotary instruments. None of the latter reports show any irreversible change. Unpublished information of the effect of ultrasonic preparation upon partially formed monkey teeth also shows the same result as that with rotary instruments.[23] The same investigator prepared cavities in deciduous teeth overlying the permanent unerupted teeth and found that no significant injury occurred.[23] It may be stated that all cavity preparation completed without excessive temperature rise causes minimal insignificant pulp injury. Ultrasonic preparation meets this requirement of safety.

In order to correlate laboratory findings with clinical practice, a survey of pulp complications following ultrasonic cavity preparation was made.[13] The total number of teeth treated was 107,198. In a period of 18 months, 124 cases of pulp pathosis were reported, or 1 out of 864 teeth. There was no way to determine whether or not the result was due to cavity preparation alone, since the teeth were also subjected to other influences which warranted treatment. There are no available data for comparison with rotary instruments. The clinical survey[13] complements the laboratory studies,[5,7,11,15,18,19,22,23] establish-

ing that ultrasonics is a safe and acceptable procedure for cavity preparation.

Technique of Use

Class I and Class V Preparations. Class I and V cavities are prepared by using a thrusting action. A suitable working point is vibrated into the tooth. In many cases, the point may be large enough to outline the cavity and provide the proper depth. For class I preparations on bicuspids, the working point may be partially rotated on its axis (Fig. 7*A*, *B*, *C*) to provide additional width. For similar preparations on molars, an oval point may be thrust to the proper depth and extended through the fissures. Class V cavities are prepared either by a working point of the size and shape of the finished preparation or, for large restorations, by extending the preparation after the initial thrusting action. When a flare and/or bevel is indicated, a cylindrical point will suffice (Fig. 7*K*). For the above preparations requiring mechanical retention, a working point in the form of an oval inverted cone will provide satisfactory results. Some operators may prefer to use hand or rotary instruments for mechanical retention and finishing enamel walls and margins.

Class III Preparations. The preparation of small class III proximal cavities presents a problem. At present, the working points are not designed to fulfill this need. Should the working point contact the adjacent tooth, it will remove enamel by planing, which necessitates protecting the adjacent tooth with a steel strip.

Large class III proximal preparations are readily prepared. The operation is essentially a planing procedure with excellent results. It should be pointed out that the completed cavity preparation should be larger than the instrument used or excessive loss of enamel and dentin will result.

Linguoproximal class III preparations are difficult. Preparation of the lingual dovetail requires indirect vision which is hampered by the slurry. The use of an aspirator is helpful but this preparation falls into the same category as upper posterior restorations in which vision is impaired.

Class IV Preparations. Class IV cavities are either proximolingual or proximo-incisal preparations. The former presents the same problems as stated for class III linguoproximal preparations. Proximo-incisal preparations are easily attained. The proximal portion is completed with a box and slice. The same slicer may be used on the incisal, the lock being established with a cylindrical working point which also will bevel the lingual walls. A beveled ultrasonic instrument provides

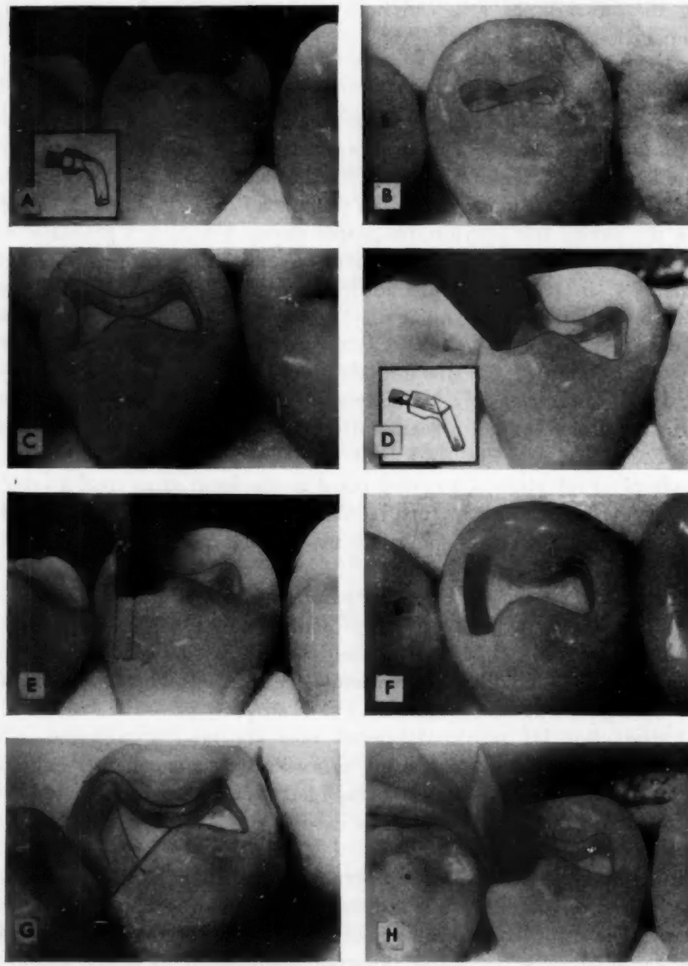

Fig. 7.

Fig. 7. *A*, Working point placed in central groove of bicuspid; note shape of working point in inset. *B*, Trough made by thrusting point in central groove. *C*, Widened occlusal portion produced by partial rotation of working point on its axis. *D*, Curved and tapered, hoe-shaped working point inserted on marginal ridge at the dentino-enamel junction. *E*, Working point thrust to depth of gingival wall; dotted line indicates depth of trough. *F*, Trough on proximal surface; note curved axial wall; proximal enamel may now be cleaved with ultrasonic working point or hand cutting instrument. *G*, Roughed-out cavity preparation after cleaving undermined enamel on proximal wall. *H*, Planing walls of proximal portion with

an excellent acute axiogingival line angle. The gingival cavosurface margin is completed with a hand instrument.

Class II Preparations. A detailed description of a class II inlay preparation on a bicuspid should illustrate the almost universal application of the ultrasonic instrument for intracoronal preparations. The illustrations are composite photographs and drawings made necessary by the lack of photographic contrast in teeth.

The class II preparation is begun on the occlusal surface. A figure 8 shaped instrument is vibrated into the mesiodistal groove to the desired depth (Fig. 7*A* and *B*). The area is then widened by rotating the working point on its axis from right to left. The result is a dovetail form with flat pulpal wall and parallel vertical walls (Fig. 7*C*).

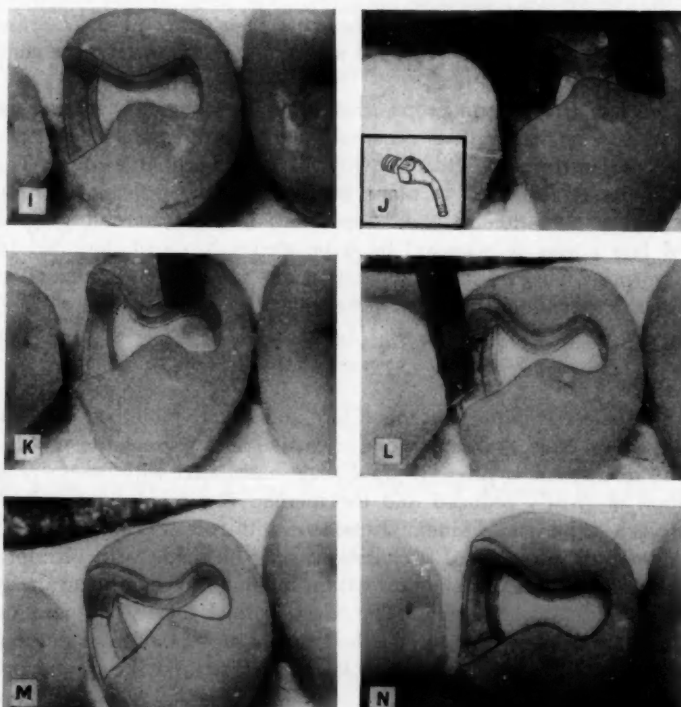

Fig. 7. (*Continued.*)

same hoe-shaped working point. *I*, proximal portion after planing. *J*, Extending and planing walls of occlusal portion with cylindrical working point. *K*, Occlusal bevel made with same working point. *L*, Marginal trimmer used to bevel axiopulpal line angle and gingival cavosurface margin. *M*, Completed cavity preparation, occlusobuccal view. *N*, Completed cavity preparation, occlusal view.

The desirable occlusal form completed, a tapering, curved hoe-shaped instrument is vibrated to the desired depth on the proximal surface (Fig. 7*D* and *E*). The precise nature of the cut may be seen in Figure 7*F*. The next operation is achieved either with the ultrasonic working point or a hand instrument. The undermined enamel on the proximal surface is cleaved, resulting in a roughed-out class II cavity preparation (Fig. 7*G*). The same hoe-shaped working point is then used to plane the buccal, lingual and gingival walls of the proximal portion (Fig. 7*H*). This operation completes the entire proximal portion except the gingival bevel (Fig. 7*I*). A cylindrical working point is then used to plane and extend, if necessary, the vertical walls of the occlusal portion (Fig. 7*J*). The same instrument is also used to bevel the occlusal cavosurface margins (Fig. 7*K*). The gingival and axiopulpal bevels are completed with a gingival margin trimmer (Fig. 7*L*), and the resultant preparation (Fig. 7*M* and *N*) meets all the requirements of good cavity preparations.

The class II amalgam preparation is similarly done. Diverging the buccal and lingual walls is accomplished by a diverging hoe-shaped ultrasonic instrument after cleavage of the proximal enamel. This instrument is also used to plane the walls of the proximal portion. Mechanical retention at the bucco-axial, linguo-axial and gingivo-axial line angles is achieved by a beveled instrument designed for the purpose. The resultant preparation meets all the requirements of a classic cavity for an amalgam restoration.

Summary

Ultrasonic technique presents a safe and effective method of cavity preparation. Noise, vibration, and excessive heat presents no problem if the instrument is properly used. Pain associated with cavity preparation is greatly reduced and the method is preferred by patients who have experienced similar treatment with rotary instruments.

Almost all intracoronal preparations may be made with ultrasonic techniques. Use in combination with a minimum of hand instruments greatly increases efficiency. The classic Black cavity preparations are readily achieved by this method. In its present state of development, it offers many advantages to the patient and the dental profession.

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2373 Abington Road
Columbus, Ohio (Dr. Postle)

The Selection and Purpose of Dental Restorative Materials in Operative Dentistry

Herbert D. Coy, D.D.S.

One of the most important requirements in any operative procedure is the selection of the most suitable type of restorative material for the individual case presented. To determine this material, the patient must be viewed as a complex human organism whose teeth are an integral part which enable him to function as a healthy being. Therefore, any consideration of restorative measures must not be limited in scope to the tooth alone but must take into account the correlation of this structure with the rest of the organism.

In order that the proper preventive or restorative measures may be carried out, it is necessary in all cases to make a thorough diagnosis, including a case history of any systemic defects that might have a bearing on oral conditions. When the health of the patient does not permit lengthy operative procedures, the selection of an otherwise inferior restorative material may be in the patient's best interests.

The problem of the selection of a material for a specific restoration is not an easy one and depends upon several factors, such as economics, caries susceptibility, health condition, age of the patient and esthetics.

The five most desirable qualities in a filling material as outlined by Dr. G. V. Black[1] are (1) indestructibility in the fluids of the mouth; (2) adaptability to the walls of cavities; (3) freedom from shrinkage or expansion after having been placed in cavities in teeth; (4) resistance to attrition; and (5) sustaining power against the forces of mastication.

Qualities of secondary importance as outlined by Black are (1) color, (2) low thermal conductivity, and (3) convenience of manipulation.

Since these qualities have become almost a universal standard, they will be accepted in this discussion as the criterion by which the various restorative materials will be appraised.

AMALGAM

Amalgam is the filling material of widest choice in single tooth restorations. More cavities are filled with amalgam than with all other filling materials combined. It is estimated that approximately 25 per cent of the professionally occupied time of the American dentist is spent in making amalgam restorations.

In evaluating amalgam by Black's five most desirable qualities of a filling material, we find that:

1. It is not altogether indestructible in the mouth. It has limited tensile strength and therefore will fracture easily in areas of thin margins. It requires bulk secured by a more box-like cavity than is required for gold foil or gold inlays to compensate for this tendency toward brittleness. In some mouths it corrodes to a degree, oxidizes, and tarnishes in the presence of sulfides. The tendency to oxidize can be minimized by thorough condensation during placement.

2. Amalgam can be readily adapted to the walls of the cavities. The utilization of this quality can be summed up in the word "condensation." Amalgam is so easily manipulated that it lends itself to inadequate handling. An amalgam filling can be a success or a failure depending upon the use of talent and ability by the operator and the conscientious employment of both. Condensation in a multiple-surfaced cavity requires a matrix to supply the missing walls. The most important adjunct of any posterior filling in cavities involving two surfaces or more is restoration of tooth form and contact. This can be done only by the aid of a suitable matrix band. A matrix should be one that will permit the restoration of tooth form and contact. It should be wedged at the gingival with a soft wooden wedge, and it should be reinforced with modeling compound to prevent movement during condensation to avoid breaking up crystallization during this operation and thus weaken the amalgam. (See Figs. 1–4.)

3. Amalgam is dimensionally stable if it is properly manipulated, but it can be greatly influenced by improper trituration, inadequate condensation and moisture contamination.

4. Amalgam has all the qualities necessary to resist the attrition of mastication if placed in a properly designed cavity and so manipulated as to give it maximum strength.

5. Amalgam has only limited tensile strength; therefore, cavities receiving it must be so constructed that all walls will meet the cavosurface at as nearly right angles as possible, to provide greater bulk of material than is necessary for gold restorations.

Of the qualities of secondary importance as outlined by Black, the

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 1. Properly placed matrix band.
Fig. 2. Properly placed matrix band stabilized with modeling compound.
Fig. 3. Proximal amalgam restorations in lower first and second molars with proper tooth form and contact.
Fig. 4. Faulty tooth form, contact and contour.

color of amalgam is not acceptable for use in anterior portions of the mouth; therefore, its use is limited to areas of the mouth where cosmetic appearance is not important.

Amalgam is a thermal conductor, and all deep cavities should be insulated.

Amalgam is easy to manipulate. This is an asset to the conscientious dentist, but this quality can be abused by the less conscientious dentist to fill cavities rather than to restore tooth form and contact, which is the most important consideration in all posterior restorations.

In a study[2] of the failure of 1521 selected cases of amalgam restorations, it was found that 60 per cent of these failures occurred because of improper cavity design. The defects of cavity preparation most commonly noted are (1) neglecting to extend cavity margins to areas of comparative immunity; (2) insufficient width to provide bulk of material; (3) failure to place the enamel rods of the gingival cavosurface in line of cleavage; and (4) inadequate retention form.

Shay and his co-workers[3] place silver amalgam high on the list of restorative materials having antibacterial effect against the recurrence of dental caries.

An amalgam filling may be a failure from recurrent caries because of faulty cavity preparation or improper handling of the material, or it may be so well made as to preserve the tooth from further carious lesions only to be lost from pathologic developments due to the failure to restore tooth form and contact. To be a successful operation, it should be so constructed as to minimize both recurrent caries and pathologic development. Steps to make this type of restoration possible are listed chronologically: (1) proper alloy-mercury ratio; (2) correct triturating time; (3) proper cavity preparation; (4) proper matrix adjustment to insure tooth form and contact; (5) proper condensation in a dry field; and (6) finishing down all margins and polishing.

Amalgam is dentistry's most valuable restorative material. It is the one which we could least afford to do without.

If the procedure as outlined is followed, there are very few carious lesions in bicuspids and molars that cannot be restored by its use with permanent and lasting results. Cavities in the distal surface of cuspids can be more satisfactorily restored with amalgam than with any other material except gold foil. This is true also of all cavities in posterior deciduous teeth and six-year molars in children.

Mosteller's examination[4] of 400 patients ranging in age from 14 to 56 years revealed that almost one-third had periodontal difficulties caused by poor restorative work.

Those who have an opportunity to view roentgenograms of many hundreds of mouths in dental clinics are amazed at the evidence which points to an appalling disregard of the value of tooth form and contact in restorations made with amalgam. This condition is the result of economics and the ease of manipulation of the material. It can be corrected by perfecting ourselves to a greater degree of skill in its use and by patient education to a higher degree of appreciation of the restorative qualities of amalgam.

Amalgam deserves a place of great respect by the dental profession. Carious teeth can be restored to health and function with it. That this is too frequently not done is operative dentistry's responsibility.

GOLD INLAYS

For restoring cavities in the posterior teeth there are three principle materials available: the gold inlay, amalgam and gold foil. In some ways the gold inlay has advantages over either of the other two. It takes more time to construct an inlay than it does an amalgam or gold foil restoration, but much of this is laboratory time, which can be delegated to a capable assistant or laboratory technician and which

actually conserves chair time for the dentist. The gold inlay also relieves both the dentist and the patient of the strain of prolonged operative sittings.

The advantages of gold inlays are (1) indestructibility in the fluids of the mouth (except the cement); (2) freedom from volume change after placement; (3) sustaining power against the forces of mastication; (4) resistance to attrition; (5) convenience of manipulation; (6) adequate crushing strength; and (7) restoration of anatomic form and assurance of a tight contact is more easily accomplished with an inlay.

The disadvantages of gold inlays are inharmonious color, high thermal conductivity, lack of adaptability to cavity walls, and the necessity for a cementing medium.

Indications for Use

1. For restoration of badly abraded surfaces where strength and resistance to the forces of mastication is of paramount importance.
2. For the restoration of badly broken-down posterior teeth where greater strength is needed than can be provided by amalgam.
3. In all class V cavities with subgingival margins where exclusion of moisture cannot be obtained for sufficient length of time to place gold foil or amalgam.
4. In mouths relatively immune to caries.
5. In teeth subject to periodontal disturbances.
6. As abutments for bridges.
7. In teeth used as rests for partial dentures.

Contraindications to Use

While gold itself is regarded by some investigators as having anticariogenic properties, the cement with which it is seated is soluble in saliva. This must be regarded as a weakness and should contraindicate gold inlays in those mouths with evident progressive caries.

Gold inlays are usually contraindicated in most class III cavities. On the distal surface of a cuspid where the maintenance of a contact is so important, gold foil or amalgam is superior to a gold inlay because they permit the conservation of tooth structure.

Gold Alloys

The research workers at the National Bureau of Standards[5] have prepared specifications for casting golds which have been adopted by

the American Dental Association and are now available from all leading dental gold manufacturers. Type A is a soft gold, type B is a medium hard gold, and type C is a hard gold.

These golds can be selected and used according to the type of cavity and the particular physical properties needed for a particular restoration.

The type A soft gold is very satisfactory in most small two-surface restorations and in class I and class V cavities.

Type B medium gold is indicated for all single restorations of more than two surfaces where the force of mastication requires moderate hardness to resist the tendency to deformation under the load.

For the most part the type C hard gold should be reserved for small, thin castings, to be used for bridge abutments or where great strength is needed for a single restoration.

Variables in Inlay Construction[6]

Inlay Wax. A properly prepared wax pattern is absolutely necessary in making an accurately fitting casting. Unsatisfactory results with waxes can arise from improper heating and overmanipulation, which produce strains in the wax that inevitably result in distortions in the casting, and from failure to allow for thermal contraction upon cooling.

An inlay wax that meets the American Dental Association Specification No. 5 stops flowing (i.e., it fits the cavity) at about 106° F.[5] No usual dental methods, including use of a matrix band with a ratchet tightening screw, will make the pattern fit after it has cooled to 106° F. Furthermore, after removal from the mouth the wax pattern will undergo further cooling to room temperature. Since wax shrinks 0.02 per cent for each degree of temperature reduction, if it is assumed that room temperature is 68° F. the temperature difference will be 38° F. (106° minus 68°) and the total shrinkage will be about 0.8 per cent. This important variable must be added to the casting shrinkage of gold if proper compensation is to be made.

Gold Alloys. As they solidify, gold alloys contract in amounts that vary with the alloy formula. Since it is impractical to change casting techniques to accommodate all of the various formulas, it is convenient to use, as a value for contraction shrinkage of gold alloys, the figure of 1.2 ± 0.2 per cent, given by the National Bureau of Standards as the best possible average.[5] This figure, added to the 0.2 per cent wax shrinkage, yields a total of 2 per cent shrinkage that must be compensated for.

The physical properties involved in casting which may be utilized

to counteract this contraction are (1) thermal expansion of the wax, (2) setting expansion of the investment, (3) thermal expansion of the investment, and (4) hygroscopic expansion of the investment, which is usually considered as a setting expansion. In the following section the various casting procedures are discussed in relation to their ability to compensate for the shrinkage of the wax pattern and the gold casting.

Casting Procedures. *Thermal Expansion Technique.* After the investment (plaster of paris and silica) and water have been mixed in proportions to yield maximal setting and thermal expansion, the case is invested and allowed to set for at least 30 minutes. In a typical product (Ransom and Randolph Gray), at this stage the maximal setting expansion in a ring cushioned with asbestos is 0.30 per cent, according to the manufacturer. After reaching its final set the investment is slowly heated in an oven until the wax has been eliminated and the mold has reached a temperature at which the maximal thermal expansion of 1.0 per cent is obtained. Thus, total setting and thermal expansion by this method is 1.3 per cent.

The double investment method requires that additional dry powder be dusted on the investment after painting with the regular mix, in order to increase the thickness of the investment surrounding the pattern. According to the manufacturer this process increases total compensation by about 0.2 per cent. However, this still leaves about 0.5 per cent of uncompensated shrinkage, and in addition, it is difficult to apply a uniform amount of powder to all surfaces and almost impossible to duplicate results.

Wax Expansion Technique. After investing the wax pattern properly in order to obtain maximal setting and thermal expansion, it is possible to return the pattern to approximately the size it was in the mouth (plus the setting expansion) by placing the invested pattern immediately in a water bath at 100° F. until setting is complete. By returning the pattern to a temperature slightly above that of the mouth, the wax shrinkage that occurred as the pattern was cooled from mouth to room temperature is completely regained, and only the casting shrinkage of the gold remains to be compensated for. By heating the mold to 1250° F. in a pyrometer-controlled furnace a further thermal expansion of 1 per cent is achieved. This 1 per cent expansion added to the 0.3 per cent setting expansion nearly neutralizes the total shrinkage and yields a close and accurate fit.

The slight distortion of the wax pattern in the water bath technique is not sufficient to prevent this from being one of the most accurate of all methods of compensating for wax and gold shrinkage.

Cristobalite Technique. In a consistency recommended by the

manufacturer, Kerr cristobalite has a total expansion of 1.8 per cent (0.4 per cent setting expansion and 1.4 per cent thermal expansion at 1300° F.), which is within 0.2 per cent of compensating for the wax and gold shrinkage.

However, a property of cristobalite investment that is not reported by the manufacturer and is not recognized by many users is hygroscopic expansion, which has been reported to vary from 1 per cent to as much as 3 per cent.[7,8] This property, though perhaps not important in large MOD and full crown patterns, can operate to produce oversize castings in three-quarter crown and two-surface inlays. This excessive expansion can be reduced by adding to the cristobalite varying amounts of a control powder which has a low thermal expansion,[9] but the method is not accurate because of the variation in amount of hygroscopic expansion in this type of investment.

Hygroscopic Expansion Technique. Scheu[7] has pointed out that merely lining a ring with wet or dry asbestos can produce hygroscopic expansion, a property which may be turned to account to compensate for shrinkage. The procedure is as follows (using Baker's hygroscopic investment as an example):

After the investment and water have been mixed as directed by the manufacturer, the case is invested and immediately placed in a water bath at 100° F., where it is allowed to reach its final set. Maximal hygroscopic expansion at this stage is 0.7 per cent, and the original shrinkage contraction which resulted from cooling the wax from 106° F. to room temperature has been nearly compensated for by placing the ring in the water bath at 100° F. After setting, the invested ring is heated slowly to a maximum temperature of 1000° F. in a burn-out oven, and kept at that temperature for 30 minutes. This investment has a thermal expansion of 0.8 per cent at 1000° F. Thus, to compensate for gold shrinkage and remaining wax shrinkage not compensated for in the water bath, there is now a total of 1.50 per cent expansion (0.8 per cent thermal and 0.7 per cent from the water bath). More expansion can be obtained, if desired for full crowns or MOD inlays, by heating the mold to 1200° F. for the wax elimination. The asbestos cushion used to line the ring should be very loose because the hygroscopic properties of the investment are easily restrained.

A relatively low casting temperature produces a smoother casting with a denser grain structure (and resulting greater strength and resistance to discoloration) than does a high temperature. Furthermore, the investment tends to break down at burn-out temperatures much above 1250° F., and the impurities given off will contaminate the gold. The surface of the investment also breaks down if the casting

temperature is too high, and will cause roughness and porosity in the casting.

In summary, there are four factors that make it practically impossible to cast to absolute dimension: (1) the susceptibility of the wax to distortion, (2) the susceptibility of the setting and hygroscopic expansion investments to restraint, (3) the variation in casting shrinkage among the different gold formulas, and (4) the variation in casting shrinkage caused by differences in shape and size of pattern. Nevertheless, it is possible to minimize the effects of the factors by proper manipulation of the materials and full use of the knowledge now available. The two techniques employing the water bath, either with thermal expansion or with hygroscopic expansion, appear to be the best for accuracy in clinical work.

GOLD FOIL

Gold foil is the most permanent of all the filling materials and has great interest for those members of the profession who are dedicated to rendering the best possible service to their patients.

Gold foil more nearly meets the requirements of a perfect filling material than any other one available. Its advantages are (1) it is completely insoluble in the fluids of the mouth. (2) It can be perfectly adapted to the cavity walls. (3) Great density can be obtained in the condensing operation. (4) The coefficient of thermal expansion is similar to tooth structure. (5) It can receive and maintain a high polish.

The three minor disadvantages are color, thermal conductivity, and difficulty of manipulation.

There are many factors to be considered which may influence the selection of gold foil as the filling material of choice: (1) the patient's mental and physical condition, age, and habits of oral cleanliness; (2) the condition of the periodontal tissue; (3) the accessibility of the cavity; (4) cosmetic considerations; and (5) the ability of the operator.

The use of gold foil is not advised in the mouths of the very young, the aged, or any person whose physical condition would contraindicate a prolonged operation. Gold foil can sometimes be used in mouths with periodontal involvements by immobilizing the tooth with modeling compound and giving attention to directing the line of force, so far as the operator is able, toward the long axis of the tooth. For the most part gold foil is contraindicated in any tooth exhibiting mobility.

Ability of the operator is all-important. In most cases it can be as-

sumed that if he has the ability to fabricate a gold foil filling, he will also have the good judgment to recognize the cases where it is contraindicated.

Indications for Use

In many class III cavities with incipient caries, it is possible to place an inconspicuous type of restoration such as illustrated in Figure 5.

Some patients prefer the use of a less permanent material rather than to display any gold in the anterior part of the mouth. In many cases of large class III cavities it would be expedient to sacrifice the

Fig. 5. Labial and lingual views of the same mouth showing nine inconspicuous class III gold foil fillings. (Courtesy of Dr. Lester E. Myers, President-Elect American Academy of Gold Foil Operators, Omaha, Nebraska.)

cosmetic appearance and place gold foil in these cavities for permanence.

In the majority of class IV cavities it is possible to place gold foil with less show of gold than can be accomplished with an inlay.

Gold foil is indicated in nearly all class V cavities in the anterior portion of the mouth. That it is not the filling material of choice in the majority of these cavities is due to the reluctance of the dental profession to tell the patients that their best interests would be served by the selection of gold foil (Fig. 6).

A large percentage of multi-surfaced cavities in bicuspids and molars can now be restored so satisfactorily with gold inlays or amalgams that it seems impractical to use gold foil for this type of restoration. The very small class II cavities in bicuspids can sometimes be restored with a combination of noncohesive-cohesive gold foil in a minimum amount of time and much more satisfactorily than with a gold inlay.

It is possible also in many class I and class V cavities to use noncohesive gold foil cylinders for the bulk of the cavity. This conserves time and such a restoration is superior to an inlay. Mat gold can also

Fig. 6. The class V gold foil in the cuspid has been in place 10 years. The silicate in the distal of the lateral and the class V direct filling resin have been in place less than 3 years.

be used to advantage in such cavities to fill in the bulk, using cohesive gold as a facing over the mat gold.[10]

Successful use of gold foil requires skill. Unlike all other filling materials, gold foil must be manipulated properly or the resultant filling becomes almost an immediate failure. A poorly fitting gold inlay will survive for a time because of the cement that holds it in place. A poorly mixed silicate cement filling will fail much sooner than a properly made one, but neither of them fails so quickly as a poorly made gold foil filling.

The dentist who masters the technique for placing gold foil has that desire to excel which compels him to master also the art of using to the utmost advantage all of the other types of filling materials. In fact, it causes him to become a skillful operator in all branches of restorative dentistry.

SILICATE CEMENTS

Silicate cement in operative dentistry plays an important part in everyday dental practice. It was estimated by Paffenbarger[5] that 11,000,000 silicate restorations were placed during 1940.

Silicate cements are no exception to the rule that the method of preparation and insertion of a given material into a cavity is distinct and important and must be adhered to for best results. When this fact is ignored, a filling will be made that is less enduring in spite of the excellence of the material.

Since many patients object to the show of metal in the anterior part of the mouth, there is great interest on the part of both the public and

the profession in any material that presents a cosmetically acceptable appearance.

There are certain inherent weaknesses in silicate cement. In order to determine where this material can best be used, it is necessary to understand its physical properties and how to use it to produce the maximum in desirable qualities.

Physical Properties

The physical properties that concern us the most are compressive strength, solubility, color stability, antibacterial action, dimensional stability, and effect on the pulp.

Compressive Strength. Silicate cement properly mixed is about one-half as strong as amalgam and just a little weaker than dentin. Unlike dentin it is extremely brittle. It can withstand considerable crushing force, but under a quick impact it chips and breaks readily. This weakness makes it unsuitable for restorations in areas of masticating stress.

Solubility. Silicate cement dissolves and disintegrates in the mouth. This is its greatest weakness, and because of this it must be considered as a temporary material.

Because of the high solubility of silicate cement, it usually fails to maintain contour and contact, which are necessary to protect the soft tissue. A tooth may be preserved from further attack by caries only to be lost from periodontal disease owing to failure to maintain proper tooth form and contact. Thus, it can be said that the high solubility of silicate cement is its greatest weakness.

Color Stability. The shrinkage of silicate cement on hardening causes a slight crevice between the filling and the tooth. The crevice harbors bacteria and food debris which discolors both the tooth and the silicate cement.

It is not difficult to match tooth shade with silicate cement, but the color stability over a period of time is very poor because of the tendency to absorb stains from food, tobacco and lipstick.

Dehydration caused by mouth breathing or allowing previously placed fillings to remain dry under a rubber dam for any length of time will cause porosity and subsequent staining. Cavity lining allowed to remain on margins will also result in discoloration.

Antibacterial Action. One of the greatest assets of silicate cement is its resistance to bacterial growth. Very few instances have been observed of the recurrence of caries under or around the margins of silicate cement fillings; this is supposed to be the result of the fluoride content of the material being released as the silicate dissolves in the oral fluids. Thus, the solubility, which is silicate cement's greatest lia-

bility, protects the tooth against further inroads of caries, which is its greatest asset.

Dimensional Stability. The silicate cements shrink approximately 2 per cent by volume on setting.

Effect on the Pulp. Before the American Dental Association through its research workers at the National Bureau of Standards set up specifications for silicate cement, it contained certain impurities. One of these impurities, arsenic, was thought to have been the source of many pulp deaths. All silicate cements that meet the American Dental Association specifications[5] now have less than two parts of arsenic in a million of the set cement.

Nearly all cements use phosphoric acid as a liquid, and it seems to be universally agreed that it is a source of damage to the pulp.

Histologic studies conducted by numerous investigators seem to establish the fact that silicate cement placed in uninsulated cavities continues to be a source of pulp irritation throughout the life of the silicate. This has never been satisfactorily explained, because Crowell,[11] and later the research group at the National Bureau of Standards,[5] have shown that over a 24-hour period the acidity of leachings from silicate cements diminishes to a *p*H close to neutrality but always remain slightly acid.

To protect the pulp against any damaging action, it is necessary to place some type of insulation between the filling and the pulp. It is recommended that cavity varnish be placed in shallow cavities and a thin layer of calcium hydroxide covered with a zinc phosphate cement base be placed in all deep cavities.

Mixing

The mixing slab and spatula should be clean and cooled to just above the dew point. The cooling of the slab is very important in order to retard the chemical reaction between the powder and the liquid. This makes possible the incorporation of a maximum amount of powder.

The set cement is substantially a gel-like substance in which small particles of powder are held in suspension. The gel is soluble, the powder particles are not; so the more powder and the less gel in the finished product, the more strength and the less solubility.

It has been shown that for every 1° C. rise in mixing slab temperature above 21° C., 0.025 gram less silicate powder can be incorporated in 0.4 cc. of liquid. If every dentist who uses silicate would strictly observe the necessity for mixing on a cool slab, the life span of silicate cements would be greatly lengthened.

Indications for Use

1. Where cosmetic appearance is more desirable than permanence.
2. Class III cavities.
3. Class V anterior cavities not extending under free margin of the gum.
4. In mouths with rampant caries.

Contraindications to Use

1. Any cavity involving masticating stress.
2. All mouth breathers.
3. Class I and class V cavities in bicuspid and molars.
4. Any cavity where a more durable restoration is acceptable.

Silicate cements are used mostly for their temporary cosmetic appearance and ease of manipulation. While their shortcomings are many, they can preserve a tooth for a period of time if manipulated to utilize the best of their physical properties. It is recommended that patients demanding this type of restoration be warned of its limitations and advised as to the care of the teeth in which it is inserted.

DIRECT-FILLING RESINS

The direct-filling resin was introduced into the United States in 1947, following the publication of the Blumenthal report.[12] It came into general use in 1949.

Cosmetic appearance in any of the easily visible portions of the mouth is so important in our present-day civilization that many patients object to restorations that display the sight of gold. This has caused the dental profession to take up eagerly any cosmetically acceptable material even though it is conceded that it has less restorative value than gold foil.

In considering the direct-filling resins, it seems fair to consider them on the basis of the same physical properties by which silicate cements are appraised.

There are many different types of resins, some others of which are now being investigated for possible use in dentistry; the present direct-filling resin is methyl methacrylate.

Physical Properties

Compressive Strength. The crushing strength of the direct-filling resin is about one-half that of silicate cement. It is very elastic in nature and exhibits a greater tendency to flow under stress.

Neither silicate cement nor direct-filling resin is suitable for use in stress-bearing areas. If occasionally it becomes necessary to yield to the appeal of esthetics and use such a material in class IV restorations, silicate cement should be the choice, for it will not stretch away from the walls under stress with the subsequent danger of recurrent caries.

Solubility. The direct-filling resin is completely insoluble in the oral fluids. In this respect it is superior to the silicate cements.

Color Stability. When the direct-filling resin was first introduced, it had a tendency to turn yellow, but the manufacturers have now remedied this defect and the majority of the resins are now color fast. Their tooth-matching quality and color stability are superior to those of silicate cement.

Antibacterial Action. The direct-filling resins are believed not to have any caries-resistant properties. In this respect they are inferior to silicate cement.

Dimensional Change. The direct-filling resin shrinks from 5 to 7 per cent by volume upon setting, which is about three times the shrinkage that occurs in silicate, but this is not as serious a defect as the coefficient of thermal expansion, which is about eight times that of tooth structure and is its greatest liability.

Effect on the Pulp. There can be no doubt that the direct-filling resins cause some pulp irritation, but there has been widespread disagreement among investigators as to the extent of the damage. Clinical investigations carried on by the author have not revealed any wholesale pulp deaths as the result of the use of this material. It is recommended as a precautionary measure that in all deep cavities a thin layer of calcium hydroxide be placed and covered with a zinc phosphate base.

Indications for Use

1. In the anterior teeth of all mouth breathers where cosmetic appearance is important.
2. In class V cavities in anterior teeth when the cavity extends under the free margin of the gum.
3. As a facing for a class IV gold inlay.

Contraindications to Use

1. In any stress-bearing area.
2. In any cavity where a more durable restoration may be placed satisfactorily.

In spite of the deficiencies of this material, it continues to hold the interest of the dental profession. There is no indication that its use will be discontinued.

Efforts have been made to reduce the coefficient of thermal expansion of the methyl methacrylate resins by various means, but none of these efforts has been successful.

A synthetic resin described by Bowen[13] has a thermal expansion similar to tooth structure. The color and strength of the epoxy resins seem to be unsatisfactory, but research continues in many areas.

It is the hope of operative dentists everywhere that the present resins can be improved or new ones developed with more nearly ideal qualities which a filling material should possess.

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Medical College of Virginia
School of Dentistry
Richmond 19, Virginia

The Amalgam Restoration

John H. Mosteller, D.D.S., F.I.C.D.

Of all the materials used in operative dentistry, amalgam is undoubtedly the most important to the average dentist. Even when it is abused, it allows dentists an opportunity to economically save millions of teeth annually; and when silver amalgam is manipulated properly and placed in a cavity of correct design a most serviceable restoration is produced.

Brekhus and Armstrong[1] found a smaller percentage of failures of amalgam restorations than of any other type, and from the work of Armstrong and Simon[2] with radioactive calcium, it appears that amalgam comes closest to hermetically sealing the cavity. While perfunctory technique is responsible for many amalgam failures, it is a relatively easy material to learn to manipulate properly.

No filling material obtains its retention in the tooth by virture of adhesion; all are dependent upon a mechanical lock. This mechanical lock may be obtained either intracoronally or extracoronally, according to the material employed. Both gold foil and amalgam must obtain their retention intracoronally, or within the crown of the tooth, while the casting may secure itself by means of extracoronal grooves or extensions. For this reason silver amalgam should be limited to those restorations that are supported by the natural tooth structure. When the tooth must be supported by the restoration, a casting is definitely indicated.[3]

When it is necessary to alter the occlusal pattern of the patient, to restore cusps of posterior teeth, or to construct three-quarter crowns, a gold casting is certainly preferable to amalgam. Although the banded crown of amalgam described by Massler and Frankel[4] is a temporary expedient, a full crown of stainless steel could perhaps be adapted as quickly and economically, and yet serve as a better restoration of the temporary tooth. From an esthetic standpoint alone amalgam must be eliminated from class III and IV cavities, with the exception of a class III cavity in the distal surfaces of cuspid teeth.

AMALGAM FAILURES

In a survey of 1000 failures of amalgam fillings, Moss[5] estimated that about 85 per cent were due to improper cavity preparation, with poor extension for prevention the most common error. At the University of Indiana in another survey of approximately 1500 amalgam failures, Healey and Phillips[6] estimated that about 60 per cent were due to faulty cavity preparation, which is a little more in keeping with my own clinical observations. Whether we accept 60 or 85 per cent, the important fact remains that at least a majority of failures of amalgam fillings are caused by incorrect cavity preparation. For this reason I shall review here the principles of cavity preparation but, owing to the scope of this paper, I shall consider only the class II cavity, which undoubtedly offers the greatest opportunity for error in preparation and which represented more amalgam failures than all other class cavities combined in the two surveys.

THE CLASS II CAVITY

The occlusal portion of a class II cavity has the same requirements as a class I: the occlusal orifice must be extended to include all developmental grooves, the pulpal floor should be flat and seated at least 1 mm. beyond the dento-enamel junction, the buccal and lingual cavity walls should converge slightly toward the occlusal surface to give the inverted truncated cone form, while the caries-free proximal cavity wall should be either perpendicular to the pulpal floor or should diverge slightly toward the occlusal surface in order to preclude the chance of undermining the intact proximal marginal ridge. Figure 1 diagrammatically illustrates this desired inverted truncated cone form, which establishes, as nearly as possible, 90 degree blunt joint margins on the filling.

Amalgam has a very good crushing strength in sufficient bulk, but frail, feather-edged margins cannot be tolerated; they will invariably fracture under the stress of mastication. A bevel must always be avoided on the margins of a cavity preparation for amalgam. If the occlusal orifice is extended the full length of the central developmental groove it will end near the intact proximal marginal ridge, which can be seriously undermined by a mesial or distal undercut; thus, a slight occlusal divergence of this proximal cavity wall is indicated (Fig. 2).[7]

The buccal and lingual walls of the proximal portion of a class II cavity should also converge toward the occlusal surface, giving the same inverted truncated cone form as that created in the occlusal por-

Fig. 1.

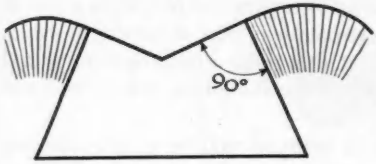
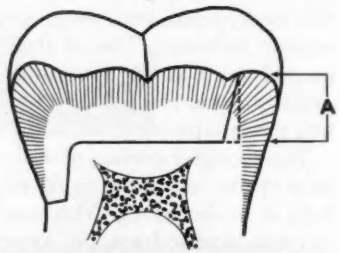


Fig. 2.



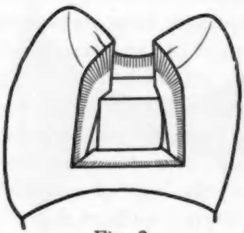


Fig. 3.

Fig. 4.

Fig. 1. The cavosurface angle should be as near 90 degrees as possible. (After Simon, reference 7.)

Fig. 2. Any undercut should be avoided at the intact proximal cavity wall. (After Simon, reference 7.)

Fig. 3. Typical class II cavity for amalgam restoration, illustrating the inverted truncated cone form. (After Simon, reference 69.)

Fig. 4. The gingival floor of the cavity is wider where it joins the axial line angles, thus creating the dovetail mortise form.

tion of the cavity from a mesiodistal view. Five benefits result from cutting the cavity walls in this manner: (1) improved resistance form; (2) improved retention form; (3) reduced chance of establishing a feather-edged margin at the occluso-bucco-proximal and occluso-linguo-proximal point angles; (4) conservation of more of the important marginal ridge of the tooth; and (5) placement of the gingivo-bucco-proximal and gingivo-linguo-proximal point angles in areas of relative immunity to caries.

Figure 3 is a drawing of a typical class II cavity for amalgam. The fact that the base of the filling is larger than the top provides greatest resistance to dislodgment of the filling from shearing forces as well as greater retention of the filling from pulling forces. There is no bevel whatsoever on the occlusal aspect of the preparation. More of the

natural architecture of the proximal marginal ridge is conserved with this cavity form, and the gingival point angles are placed in areas of relative immunity. One of the most common sites of recurrent caries around any class II restoration is at the gingivo-bucco-proximal and gingivo-linguo-proximal point angles; they should be placed well out into the interproximal embrasures.

The proximal portion of a class II cavity should be as self-retentive as possible and not entirely dependent upon the occlusal portion to hold it in the cavity. This can be accomplished by establishing the dovetail mortise form, i.e., greater occlusal convergence of the bucco-axial and linguo-axial line angles than the occlusal convergence of the buccal and lingual walls of the proximal portion of the cavity (Fig. 4).

The dovetail mortise form and the gingival retentive groove are the ideal features of a class II cavity preparation for amalgam, but they cannot always be used. Frequently the operator must restore teeth in which the carious process has destroyed most of the internal structure of the tooth and no proximal step can be established at all. In such cases the gingival floor of the cavity will be level with the pulpal floor of the occlusal portion of the cavity. A proximal step can be built with cement, but a true dovetail mortise form is difficult to establish and we seldom attempt to do so. Due to the bulk of amalgam in a restoration this deep, if the buccal and lingual walls of the proximal portion of the cavity are converged gingivo-occlusally and the isthmus connecting the proximal and occlusal portions of the cavity is generously wide, we need not worry about the filling coming out.

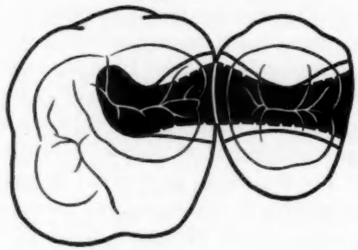
From an occlusal view there are two important considerations as to the extension of the buccal and lingual margins of the proximal portion of a class II cavity for amalgam:

1. The proximal margins should be extended far enough out into the buccal and lingual embrasures to place them in areas of relative immunity to recurrent caries.

2. The proximal margins should form as nearly as possible a 90 degree angle. This is what we refer to as a "blunt joint margin."

Figure 5 is a drawing of the correct and incorrect outline forms for the proximal margins of a class II cavity for amalgam. Underextension not only invites future decay but also makes it impossible to properly finish and polish these margins of the filling. The operator must not carry this extension too far lest the margins be too greatly flared. This error results in the complete destruction of the proximal marginal ridge of the tooth and the formation of feather-edged margins on the amalgam filling, as shown in Figure 6. The margins should be extended only so much as is necessary to remove all clinical signs of decay and place them free from contact with the adjacent tooth.

Fig. 5.



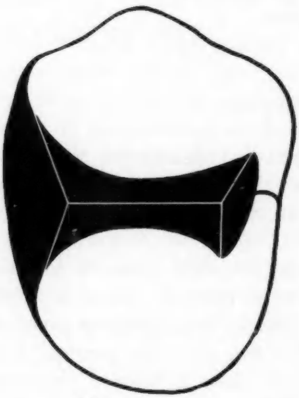


Fig. 6.

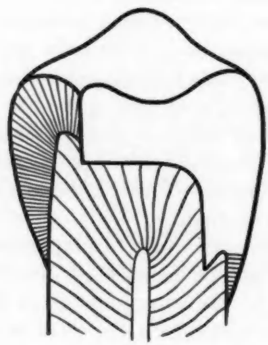


Fig. 7.

Fig. 5. Correct and incorrect outline forms for the proximal margins of a class II cavity. (After Ingraham, reference 8.)

Fig. 6. Feather-edged margins of amalgam are always subject to fracture.

Fig. 7. The axiopulpal line angle is beveled and a gingival retentive groove may be added.

There is nothing to indicate any advantage to a greater extension as far as the prevention of recurrent caries is concerned, and it greatly weakens the tooth.

MOD Cavities

When both proximal surfaces of the tooth are involved with caries, two class II cavities are prepared and joined on the occlusal surface. This is always the correct procedure in lower molars and upper bicuspid teeth because of the continuous anatomy of their central development grooves across the occlusal surface. In upper molars with a very prominent oblique ridge it is permissible to prepare two sep-

arate class II cavities separated by this ridge if it has not been undermined by decay. In this manner the architecture of the tooth is best preserved and the tooth is not as weakened as when the buccal and lingual cusps are completely separated by the occlusal portion of the cavity. Some authors advocate the placement of two separate class II cavities, separated by the prominent buccal cusp ridge, in the lower first bicuspid. This is suggested, of course, with the same idea of conserving the strength of the tooth; however, I do not feel that the average lower first bicuspid is large enough to prepare conveniently two separate cavities with proper retention form without joining them on the occlusal surface. The tooth need not be seriously weakened by this connection on the occlusal surface.

When both proximal surfaces are carious and a mesio-occluso-distal cavity must be prepared, the occlusal portion of the cavity is extended like any class I cavity with the exception of the bicuspids, in which case the isthmus joining the two proximal cavities must be wider than normal in order to give the amalgam the necessary bulk for strength in this area. Black's suggestion that this isthmus be one-third of the buccolingual width of the occlusal surface of the tooth may well serve as a guide.

There are details in preparation of the class II cavity for amalgam that must be considered. The first of these is the axio-pulpal line angle, which is the junction of the pulpal floor of the occlusal portion of the cavity with the axial wall of the proximal portion. This line angle should be generously beveled when a definite proximal step exists, in order to give sufficient bulk to the amalgam in this area (Fig. 7). Some authorities have stressed the desirability of placing a bevel on the gingival margin. If this margin ends near the cemento-enamel junction there is a possibility of leaving a few short enamel rods that will not communicate with dentin unless the margin is beveled. Figure 7 shows that the rods do not take an apical slant until near the cemento-enamel junction. If the gingival margin ends higher on the proximal surface, the direction of the rods precludes any necessity of a bevel, and if the margin ends on cementum there is of course no indication for a bevel either. The clinical significance of a beveled gingival margin for amalgam restorations, regardless of the level of this margin, is questionable. Any very short rods left without dentinal communication are not subject to occlusal stress, and I would much prefer to condense amalgam against a squared margin than a beveled one. While an actual enamel ledge along this gingival margin cannot be tolerated, whether or not the gingival margin is beveled is probably the least important consideration we will make in this paper.

In healthy young patients this gingival floor is carried down to the

level of the free gingiva in order to enjoy the caries immunity offered by the secretions of these tissues. While it is true that the gingival margins of restorations so placed do not always remain under the gingiva as the teeth continue to have passive eruption due to occlusal attrition, and the free gingiva itself recedes, this susceptable proximal area is at least protected during the years when the individual is most likely to experience interproximal decay. In older patients in whom there is considerable gingival recession or when the operative work is done following a gingival resection, this gingival margin is carried down sufficiently low to remove all clinical signs of caries and to place the margin of the amalgam filling out of contact with the adjacent tooth.

PULP PROTECTION AND CAVITY STERILIZATION

I have long felt that it is near malpractice to do operative dentistry without applying some sort of coolant to the tooth during the cutting of the cavity; with more men using increased speeds with the rotary cutting instruments, the use of coolants is mandatory.

On the other hand, after an extensive review of the literature I can find little to justify the use of any drug for so-called cavity sterilization prior to the insertion of the filling.

THE INTERMEDIATE BASE

The use of intermediate bases under amalgam restorations has been considered good technique for many years, but some men still employ an oxyphosphate of zinc cement for this purpose. The literature is replete with histologic evidence of pulpal injury from cements containing orthophosphoric acid except when placed in very shallow cavities.[9-14] The mechanical intervention of cavity preparation itself causes an inflammatory reaction in the pulp except under the most judicious application of the rotating cutting instruments. In place of the irritating zinc cement should be substituted a eugenol-containing base material, for not only is there no reaction in the pulp to this material but also it is capable of preventing the inflammatory changes that result from cavity preparation.[10,15] There are several proprietary preparations of zinc oxide and eugenol cements on the market, and Staybelite resin or asbestos powder can be added to a conventional mix of zinc oxide and eugenol to increase its crushing strength; but none of these materials tested withstood pressures in excess of about 4500 lbs. per sq. in., which is far below the most effective packing pressure of

amalgam. In other words, a substantial foundation for the immediate insertion of a well condensed amalgam restoration is not provided.

To protect cut dentin from stimulation, a non-irritating cement base of medium crushing strength should be used.[16]

SELECTION OF ALLOY

There are three paramount advantages of using a fine cut alloy:[17]

1. Better Control of Dimensional Changes. A number of investigators[18–21] have reported that variations in trituration or in condensation pressure have a smaller effect on dimensional changes in fine cut alloys, thus allowing more latitude of manipulation. We could never condone perfunctory technique in the manipulation of amalgam, but it is only common sense to use a material which offers a wider margin of error. There are three chief reasons why we enjoy this better control of dimensional changes:

a. Reduced Expansion. Expansion has been shown to be a linear function of the surface area of alloy particles.[22] In other words, fine cut alloys, with more surfaces to be attacked by mercury, produce less opportunity for expansion than do regular and coarse cut materials, and thus have a wider range of manipulation that will still result in amalgam that is free from excessive expansion.

b. Less Trituration. Owing to the decreased particle size and corresponding increased surface area to be attacked by mercury, a shorter mixing time is required by fine cut amalgam alloys. The common tendency to undermix will result in excessive expansion. If less trituration is required there is less chance of undermixing.

c. More Complete Expression of Mercury. With the more complete amalgamation of the fine cut alloys the expression of free mercury is facilitated. The deleterious results of the presence of excess mercury in an amalgam restoration are decreased crushing strength, decreased resistance to tarnish, and increased expansion.[23]

2. Greater Crushing Strength. Not only is the ultimate (or 24 hour) crushing strength of a fine cut amalgam greater than that of a coarse cut one, but of more dramatic importance is its increased early crushing strength. It takes a large cut material approximately 6 hours to develop the same strength possessed by a fine cut alloy at the end of 3 hours.[22,25,26] Many amalgam failures are caused by fracture of the material, and while all amalgam restorations should be protected from masticating stress for 3 to 4 hours, there is less opportunity for fracture of the fine cut amalgam due to inadvertently applied pressure.

3. Smoother Surface on the Completed Restoration. Owing to the greater homogeniety of the material and the facilitated expression of

free mercury, a fine cut alloy restoration offers a smoother surface which facilitates carving, finishing, and polishing. A lasting furbish cannot be expected unless a macroscopically smooth surface is first established, and this surface is more easily obtained with the fine cuts.[27]

MOISTURE CONTAMINATION

While it would be fatuous to say that any one thing is the most important link in the chain of the amalgam technique, undoubtedly one of the most frequently committed errors in manipulation is contamination with moisture. Any zinc-containing alloy that is contaminated with moisture, whether it be from the palm of the operator's hand or the saliva of the patient, will expand prodigiously,[28-30] lose up to one-third of its ultimate strength,[31] and tarnish badly. For this reason the material should not be handled with the hands but placed in a linen squeeze-cloth for expression of the free mercury and mulled in a piece of rubber dam or a rubber thumb stall to maintain plasticity. Expansion from moisture contamination can amount to as much as 300 microns per centimeter and is very evident clinically. Claim has been made that if the zinc content of the alloy is low enough there will be no delayed expansion of the material even though contaminated with moisture,[32] but other investigators have been unable to substantiate this.[33] Moisture contamination cannot be tolerated in any zinc-containing amalgam.

While I would never discourage any person from using the dam, it should be understood that through care and the use of good absorbants and aspirators, as well as the occasional use of an antisialogogue, a dry cavity can be maintained in at least 90 per cent of the cases and if the material is manipulated properly and placed in a cavity of correct design, an amalgam restoration can be built that is second to none. If the dam is used I feel that it should not be applied until at least a majority of the cavity preparation has been completed, to allow the operator to work under a stream of water in order to protect the pulp. The condensed amalgam can be flooded with water or saliva without affecting the dimensional change or crushing strength.

NON-ZINC ALLOYS

Although non-zinc alloys were first introduced many years ago there has been a renewed interest in them during the last few years and several new ones have been placed on the market. The contamination of a non-zinc alloy will not result in the delayed expansion or loss of strength characteristic of the alloys containing this element, but

Sweeney[34] reported pitted surfaces on fillings built of moisture-contaminated non-zinc amalgam. The author restored 250 tooth surfaces with an experimental non-zinc alloy, not available on the open market at the time of this writing.* Most of these fillings have been examined at the end of thirty months. Those fillings made of moisture-free non-zinc alloy appear clinically to be as good as, and have maintained a polish as well as moisture-free zinc-containing amalgam fillings in the same patients' mouths. Those fillings made of contaminated non-zinc alloy, although exhibiting no clinical signs of dimensional change, are more severely corroded and tarnished than moisture-contaminated zinc-containing amalgam fillings in the same mouths. Zinc serves as a flux during the manufacturing process of amalgam alloy and it is possible that the non-zinc alloy contains more oxides than the zinc alloy, thus being more susceptible to tarnish and corrosion. Absolute dryness is essential with either a zinc or a non-zinc alloy if the filling is to remain free of corrosion, and since I prefer the working properties of the zinc-containing materials, I see no advantages to the use of the non-zinc amalgams at the present time, save perhaps in some instances in pedodontics.

MATRIX ADAPTATION

In the class II cavity the adaptation of the matrix is very important, for it shapes the missing wall that is to be restored with amalgam. Many different mechanical matrix retainers have been in use for years but most good clinicians have felt that none of these reproduced the proximal surface of the tooth and have therefore used individually tailored bands supported by a gingival wedge and modeling compound. A small strip of 0.002 stainless steel matrix band material is contoured with contouring pliers (Fig. 8) and inserted in place on the proximal aspect of the cavity (Fig. 9). The band is wedged at the gingiva (Fig. 10) and secured with flame-softened compound (Fig. 11). If the band needs adjusting, a warm plastic instrument is pressed against the cavity side of the band and the heat melts the compound, allowing movement of the band in the desired direction.

There is a mechanically retained matrix available, however, that does accurately conform to the contour of the tooth. Tofflemire designed a retainer and band that serves very well as a matrix for class II cavities for amalgam. While the retainer itself is mechanically excellent, the success of this matrix is based mainly on the shape of the band. The earlier preformed bands were a section of a cone, made by cutting parallel arcs which yielded segments of a 360 degree circle

* Supplied by Baker and Co.

Fig. 8.

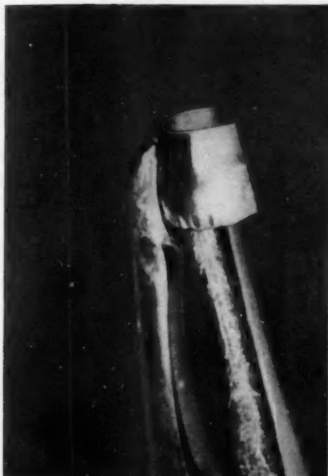


Fig. 9.

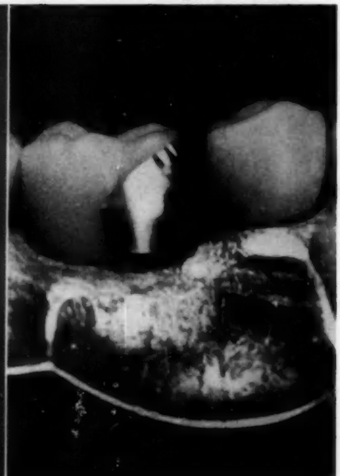


Fig. 10.

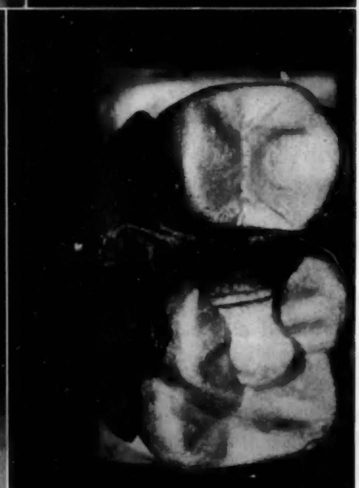


Fig. 11.

Fig. 8. Contouring matrix band. Light pressure should be used and the process repeated until a suitable convexity is obtained. (Figs. 8–11 courtesy of E. C. Miller, reference 61.)

Fig. 9. Contoured band in place. The proximal surface anatomy is reproduced.

Fig. 10. Band wedged into place has been contoured so that there is adjacent contact.

Fig. 11. Complete matrix. Flame-softened compound is inserted into the embrasures and extended to include the buccal and lingual surfaces of the adjacent teeth.

(Fig. 12). The idea of the arc was to make the gingival end of the band smaller than the occlusal. This principle would be correct if teeth were round like a pipe, but teeth are not round. They are convex on their buccal and lingual surfaces but have more or less flat proximal surfaces, similar in shape to a parabola. In an effort to obtain this parabolic shape Tofflemire first designed a band former which, by means of a protractor, could fold band material to create an arc of any angle (Fig. 13). Using hundreds of extracted teeth he determined the

Fig. 12.

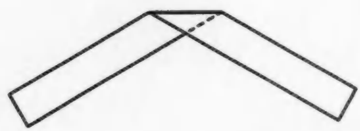


Fig. 14.

Fig. 12. Conventional arc band which is a segment of a 360 degree circle.
Fig. 13 (center). Folded band material in search of correct arcuate angle.
Fig. 14. Tofflemire arcuate matrix band.

correct arcuate angle which gave the desired progressive occlusal flare and allowed close adaptation of the band to the two convex and two flat surfaces of the tooth and yet established the proximal marginal ridge in contact with the adjacent tooth. Once this arcuate angle had been determined, a die was made filling in the occlusal and gingival deficiencies of the folded band at the fold, and a continuous arcuate band resulted (Fig. 14). A unique advantage of the Tofflemire retainer is that it can be applied from either the buccal or the lingual surface because there is an angle in the shank of the instrument (Fig. 15). The gingival wedge is usually indispensable in the construction of a class II amalgam restoration. Overhanging gingival margins cannot be tolerated in the most immaculate mouths and they substantially increase the burden for those who have difficulty with their oral hygiene.[35] The wedge should be of wood and should be moistened before insertion to obtain the snugness assured by the resulting slight

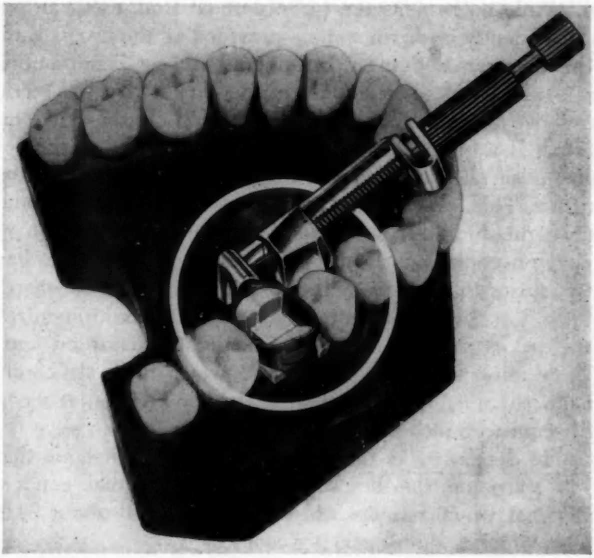


Fig. 15. Tofflemire matrix retainer and arcuate band in place, from the lingual aspect of the tooth.

expansion of the material. If it is inserted below the gingival margin an overhang is invited, and if it is inserted above the margin a concave proximal surface will result. The force of the cheeks and the tongue creates a horizontal food pack in such improperly contoured interproximal embrasures. The superior border of the wedge should be flush with the gingival margin of the cavity.

When the cavity is viewed occlusally, it is possible to ascertain whether the wedge is to be inserted buccally or lingually, according to the buccolingual inclination of the tooth. In about 70 per cent of the cases, the lingual embrasure is the larger and the wedge must be inserted from that side. In a few cases it will be necessary to insert wedges from both sides to gain a close adaptation of the matrix band.

PROPORTIONING OF ALLOY AND MERCURY

Gray[36,37] pointed out the importance of proper alloy-to-mercury ratio 35 years ago, and the ratio recommended by the manufacturer of the particular brand of alloy employed should definitely be adhered to. If less mercury is used, the working plasticity of the material is impaired and the filling will corrode owing to the scabrous surface formed by the many unamalgamated particles which the mercury fails

to coat. While no benefits are to be derived from using an excess of mercury, evidently no harm is done provided all the excess is removed from the amalgamated mass before and during condensation. The danger in using an excess amount of mercury is that the tendency is not to remove all of it.[24] The deleterious results of excess mercury have been listed. If a high ratio of mercury is used in the mix, a considerable amount of alloy is removed in solution when the excess mercury is expressed. This leaves a very small mass of amalgam in comparison to the weight of alloy used; therefore, the use of a high ratio of mercury is uneconomical. It also increases the possibility of having to make two mixes to fill a cavity the size of which does not warrant the second mix. Large restorations frequently require multiple mixes, since amalgam that is over 3 minutes old should be discarded and excessively large mixes should be avoided. However there are certainly no advantages to using two mixes for a smaller filling; the second mix merely becomes an inconvenience.

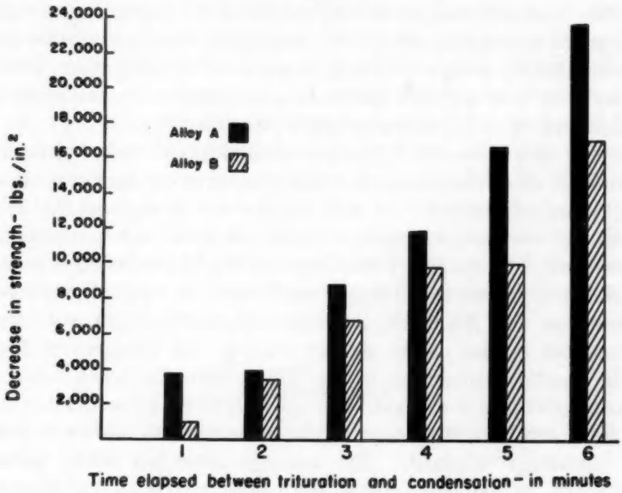
Figure 16 demonstrates the loss in strength of amalgam that is allowed to stand on the bracket table before actual condensation. Amalgam that was 6 minutes old showed a loss of about 24,000 lbs. per. sq. in., which is almost a 50 per cent loss.

Since the proportioning of alloy and mercury is not a critical measurement, we see no need for elaborate scales or balances. The Crandall scale is excellent if the recommended ratio is used. Some manufacturers package their alloy and mercury in separate preweighed capsules which many men find convenient. The gravity drop or volume dispensers used by the majority of dentists will suffice provided the measuring device employed was designed for the particular brand and cut of alloy used.

MIXING OF ALLOY AND MERCURY

It is possible for the careful operator to obtain a good mix with either the mortar and pestle or the rubber thumb stall technique; however, consistently good mixes can be more easily obtained with a mechanical amalgamator that has a time interval regulator. The amalgamator is particularly convenient when it is necessary to make multiple mixes for extensive restorations. The main criticism that has been leveled at the mechanical mixers has been that there is a greater chance of getting an overmix, or what has been called secondary trituration. An overmix of amalgam is almost an impossibility clinically. The material would have to be mixed to a point that it would not have sufficient plasticity to allow the operator to condense the filling properly. A slight overmix in comparison to what has been con-

Fig. 16.



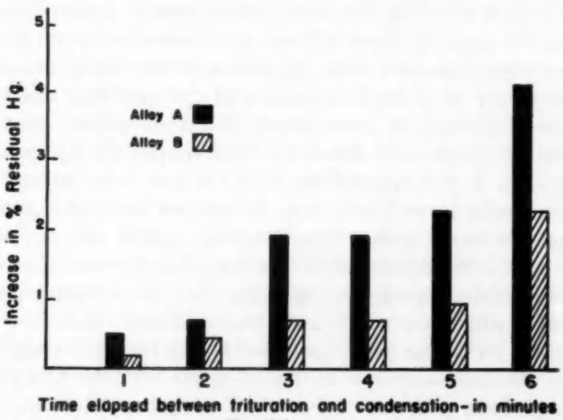


Fig. 17.

Fig. 16. Loss of strength of amalgam due to delay between mixing and condensation. (Courtesy R. W. Phillips, Indiana University School of Dentistry.)

Fig. 17. Increase in mercury content of amalgam due to delay between mixing and condensation. (Courtesy R. W. Phillips, Indiana University School of Dentistry.)

sidered normal in the past is exactly what I wish for, but I prefer to term this "more thorough" mixing rather than overmixing. Amalgam that is more thoroughly mixed will be slightly stronger, will be free of detrimental expansion, will have better working properties, and will take and maintain a polish better than material either undermixed or mixed according to the manufacturer's directions.[38]

The fear of an overmix by some essayists has been based on a fear of shrinkage of the material. It is true that if most brands of alloy are more thoroughly mixed they will usually fail to expand the 3 to 13 microns per centimeter required by the present A.D.A. Specification for amalgam. The theory of this required slight expansion is based on the difference between the linear coefficients of thermal expansion of the amalgam and the tooth, with the idea that a slight expansion of the material in the cavity during setting will compensate for the slightly greater contraction of the filling than the tooth when submitted to cold drinks or food. This appears to be of academic interest only, for several investigators[39-41] have reported an inability to demonstrate shrinkage clinically. The average amalgam filling measures about 5 mm. or less across its widest occlusal portion, and thus material that contracts 3 or 4 microns per centimeter in the testing laboratory would result in about a 2 micron or less contraction in the filling, which simply does not show up clinically. The Specification is based on the theory of a slight expansion of the amalgam causing a compression of the dentin, but naturally the all-important consideration is the enamel margins and doubt has been frequently expressed as to the ability of a slightly expanding filling to compress enamel. Such expansion would more likely occur linearly or occlusally along the line of least resistance, rather than laterally against the confining cavity walls. It must be remembered that the laboratory tests are conducted on non-confined specimens that are free to expand equally in all directions, which is certainly not the case in the mouth.

About 10 microns per centimeter is the maximal contraction that can be obtained with any alloy that meets with the A.D.A. Specification regardless of the mixing time. Clinical observation for three years at the University of Indiana of amalgam restorations fabricated from a special formula alloy, which contracted over 30 microns per centimeter in the laboratory under the same manipulation used in the clinic, failed to demonstrate a single case of shrinkage of the material.[42] The ditch that is frequently seen around amalgam fillings and has been attributed to contraction is usually caused by poor condensation and adaptation of the amalgam, the pooling of free mercury at the margins, or the fracture of a feather-edge amalgam margin.

On the other hand, day-to-day clinical observation will reveal many cases of expansion, and amalgam that is undermixed will usually ex-

pand prodigiously. While more thorough mixing of amalgam is advocated, the placing of partially crystallized material back into the amalgamator and remixing in order to regain plasticity must certainly be condemned. A very weak and poorly adapted filling will result from the use of such material, as illustrated by the information in Figure 16. Partially crystallized amalgam should be discarded and a second mix made; this can easily and rapidly be done with a mechanical amalgamator. It is permissible and often advisable to mull the material a few times in a clean piece of rubber dam during the period of condensation in order to maintain the desired plasticity. Mercury cannot be added to partially crystallized amalgam and then remixed without resulting in a restoration that will be plagued with all the disastrous results of excess mercury.

CONDENSATION

Any successful amalgam technique is dependent upon the careful execution of each of the numerous steps in the procedure, and it has been justly said that the most important step is the one you are performing at the time. Various authors have recognized the deficiencies caused by poor condensation, such as marginal failure,[43] lowered resistance to tarnish,[44] increased expansion, and reduced crushing strength.[23] Although the majority of dentists have been taught that the proper consistency for the initial condensation is one rich in mercury, or a wet mix, this idea is a fallacy. Extra dry amalgam used at the top of the filling, with the hope of taking up this excess mercury from the more plashy condensed mass, does not join the already condensed material and results in a granular surface which will not retain a lasting furbish. We can not hope for a diffusion of the free mercury through the progressively less plastic amalgam, and therefore there will be produced a restoration with a high content of detrimental mercury. Strader[45] found that specimens packed with this wet mix expanded over three times as much as those condensed with a consistently dry mix from top to bottom. Sweeney[39,46,47] and Miller[48-50] repeatedly insisted upon a uniform consistency from top to bottom of the filling. A uniformly dry mass from start to finish of condensation results in amalgam of greater homogeneity, which reduces dimensional change and increases crushing strength and resistance to tarnish.[51]

REMOVAL OF MERCURY

The excess mercury should be removed with a linen squeeze-cloth in order to avoid contamination with perspiration from the hands of the assistant or the operator. Strong finger pressure is used but it is

not necessary to resort to pliers unless the work is being done by a very weak assistant. We wish for the material to be dried to a consistency such that a slight amount of free mercury will appear under heavy packing pressure. Many men have suggested that the free mercury be removed from only that small portion of the mass to be condensed first, leaving the mercury in the rest of the material in order to retard setting. The mercury is then removed from each portion of the amalgam just before it is condensed into the cavity. Unfortunately, crystallization and setting of amalgam are not synonymous, and while the presence of the mercury will retard setting, crystallization still takes place and results in an inability to remove as much mercury from the mass. Harvey[23] found that the safe working time of amalgam was not related to the percentage of mercury it contained, although its setting time was. Figure 17 demonstrates the increase in percentage of mercury in specimens packed with amalgam that had been allowed to stand on the bracket table for a few minutes before condensation. Amalgam 3 minutes old released only half as much mercury as freshly mixed amalgam did. Specimens packed with 6 minute old amalgam had four times as much mercury in them as specimens packed with 1 minute old material. We therefore recommend that the free mercury be expressed from the entire mass as soon as it is taken from the capsule of the mixing machine. Workable plasticity can be maintained by mulling the material several times in a piece of rubber dam during condensation. The amalgam should appear dry but still yield a slight amount of free mercury under heavy packing pressure.

Heavy packing pressure should be used, condensing the material in many and small increments, and the occlusal portion should be overpacked and then the excess carved away with sharp instruments. In the case of a class II cavity, the occlusal excess may be carved away immediately, but the matrix band should not be disturbed for at least 3 minutes. Much has been written about the correct direction in which to remove the matrix band, but if the material has been well condensed and allowed to set for a few minutes, the band can be removed safely from any direction.

AUTOMATIC VS. HAND PACKING

One of the characteristics of the dental profession is to seek new gadgets that will make a technique foolproof, rather than to endeavor to adhere to principles of procedure. Hollenback developed the pneumatic condenser for gold foil and Sweeney was one of the first to adapt it to the condensation of amalgam, and through his prolific writings[39,46,47,52,53] probably did more to popularize mechanical condensa-

tion than any other person. A number of men have recommended mechanical condensers in the literature,[54-59] but it has been personal testimony only. Other essayists[51,60-62] have concluded that equally good results can be obtained with hand technique, and Markley[63] is very critical of any type of mechanical condenser. He warns of the danger of the mallet type of instrument fracturing enamel margins, and feels that the vibrator type does not actually condense and adapt the material but merely continues trituration in the cavity. Miller[64] has expressed this same fear. With the use of the vibrator type of gadget, mercury tends to collect at the all-important margins of the filling owing to the jarring rather than compression of the amalgam. Phillips[65] compared specimens of fifteen different brands of alloy when packed by hand and with the pneumatic instrument; while the pneumatically condensed specimens were slightly stronger, the difference was of academic interest only. Taylor and his co-workers[25] conducted a study of five different brands of alloy when condensed by hand, by the pneumatic condenser, by a mechanically activated packer, and by a vibrator type of instrument, and found no improvement in the crushing strength with any of the three different types of mechanical condensers over hand packing.

The choice between hand and mechanical condensation appears to be one of personal clinical preference only.

CARVING, FINISHING, AND POLISHING

It is not important what amalgam restorations are carved with but that they are carved. Most dentists have their pet carvers, just as golfers have their pet putters; but for those who have not been carving their amalgam fillings or who have had difficulty in deciding on instruments for this procedure, we would like to suggest the ones that we have found very easy to manipulate.

As previously stated, the occlusal excess can be removed immediately but the matrix band should not be disturbed for 2 or 3 minutes. This occlusal excess is removed with either a discoid or the spoon end of a No. 4 Bredall amalgam carver (Fig. 18). On small bicuspids I use the discoid, and the Bredall instrument on all others. After the matrix band has been removed, the buccal and lingual margins of the proximal portion of the filling are carved down flush with the cavity margins, using the pointed end of the No. 4 Bredall carver (Fig. 19). This long, fine-pointed blade is most convenient to remove any slight excess that may exist at the gingival margin also. A medium-sized cleoid is employed to carve the cuspal slopes and developmental grooves (Fig. 20). This little plow-shaped instrument is very easy to

use and almost automatically gives the proper cuspal slope while carving the occlusal grooves in the anatomy. These grooves are dressed down and rounded with the small end of a No. 7 Hollenback burnisher (Fig. 21).

This is the only indication for the use of a burnisher on an amalgam filling. I merely define the developmental grooves with this instrument.

Fig. 18. Fig. 19.

Fig. 20. Fig. 21.

Fig. 18. Spoon end of No. 4 Bredall amalgam carver.
Fig. 19. Pointed end of No. 4 Bredall amalgam carver.
Fig. 20. Developmental grooves are carved with a cleoid.
Fig. 21. Grooves are rounded with the small end of a No. 7 Hollenback burnisher.

Burnishing the surface of the filling will result in the pooling of mercury at the margins of the restoration (Fig. 22). Some dentists attempt to put a psuedo polish on an amalgam filling with a burnisher at the time it is inserted. This glossy appearance will not last, and the margins of the restoration will be plagued with the deleterious results of free mercury. After completing the carving, the filling may be smoothed with a moistened pellet of clean cotton, but actual finishing and polishing must be deferred for a minimum of 24 hours, and preferably a week or more.

Few dentists would consider placing a gold inlay in a patient's mouth without first finishing and polishing the casting to its maximal luster. The obligation to finish alloy restorations in this same manner is not felt to the same extent. The three main reasons for this lack of thoroughness in amalgam restorative work are (1) inadequate fees for silver fillings, (2) lack of conviction that a well finished and polished amalgam filling is superior to an unpolished one, and (3) the fallacy accepted by many dentists that amalgam will not retain a polish. The fee problem in operative dentistry deserves a separate essay. The author justifies the time spent in finishing and polishing amalgam fillings by realizing three things. The only definite way to establish a positive margin of enamel and amalgam at the same level is to finish and polish that margin a minimum of 24 hours after insertion of the filling. Also, well finished and polished amalgam restorations promote better oral hygiene. People take the best care of things they are proudest of to own and too few patients have been given a sense of pride in owning an amalgam filling. If the dentist will take a hand mirror and show the patient his properly finished restorations most usually the patient will develop a pride of ownership that will stimulate better oral hygiene. With more teeth lost from periodontal disease than caries in adult patients, what could be more important than promoting better oral hygiene? And lastly, well finished and polished amalgam restorations will command appreciation from my patients and demand respect from my colleagues, two things that most of us are desirous of in the dental profession.

Properly manipulated amalgam will remain free from tarnish or corrosion in all but the most unhygienic mouths.[66] If an amalgam restoration fails to retain a polish in the mouth of a patient who exercises acceptable oral hygiene, failure is usually due to one or more of the following reasons: (1) *The dentist attempted to polish a rough and scabrous surface.* This surface can be caused by undermixing or light packing, or it may be due to failure to establish a macroscopically smooth surface on the completed restoration before attempting to polish it. (2) *The restoration is rich in excess mercury.* Regardless of the time spent in polishing an amalgam filling, if it contains excess free mercury, it will tarnish.[24] This is an insoluble tarnish of mercuric sulfate formed by the oxidation of the mercuric sulfide that results from fermentation of foods in the mouth. This tarnish may be removed and the filling may be repolished, but it usually turns dark again. (3) *The filling was contaminated with moisture.* This is a true corrosion that extends all the way through the material and that cannot be removed by repolishing. If this type of filling is removed, it will be found that even the dentinal floor of the cavity is discolored.[67] It is the

responsibility of the dentist to avoid all three of these errors in the manipulation of silver amalgam.

Technique for Finishing and Polishing. First, any discrepancy in the level of the amalgam and the enamel on the occlusal margins is reaccomodated with a small carborundum stone (Fig. 23). The buccal and lingual margins of the proximal portion of the restoration are finished with medium coarse grit sandpaper disks (Fig. 24). I do not

Fig. 22.

Fig. 23.

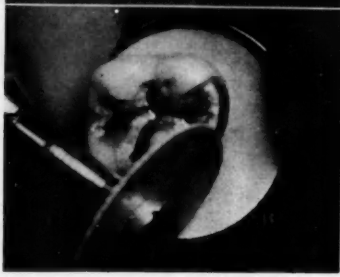


Fig. 24.

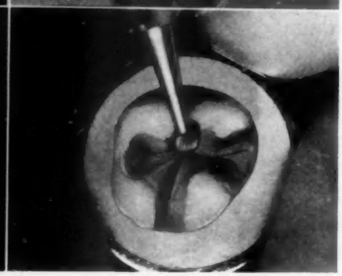


Fig. 25.

Fig. 22. Mercury at the margin of a burnished amalgam filling. (Courtesy D. A. Keys, University of Nebraska College of Dentistry.)

Fig. 23. Occlusal margins are adjusted with small carborundum stone.

Fig. 24. Proximal margins are made flush with sandpaper disks.

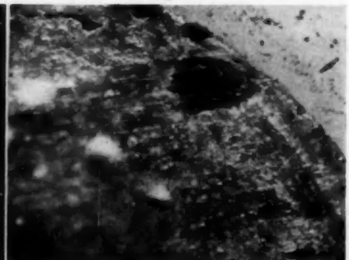
Fig. 25. Gross roughness is removed by dull finishing burs.

attempt to separate the teeth and polish the proximal contact. There is nothing to be gained by polishing this material that has been condensed against a clean strip of stainless steel, and most operators will do more harm than good with the use of separators. There is likewise always the chance of losing the interproximal contact. The gross roughness of the occlusal surface is now removed with dull round-plug finishing burs (Fig. 25). Old burs are used, or else new ones that have been left in water over night, in order not to remove too much material with any sharp blades. The final glossy smoothness is obtained

with a midget rubber sulci disk (Fig. 26). To obtain the greatest surface coverage and promote the longest life of the rubber disk, midget-headed mandrels should be used concomitantly. The application of these rubber disks must be under water to prevent overheating both the filling material and the tooth. Clinical observation will reveal occasional amalgam fillings that have a frosted appearance, like a mirror

Fig. 26.

Fig. 27.



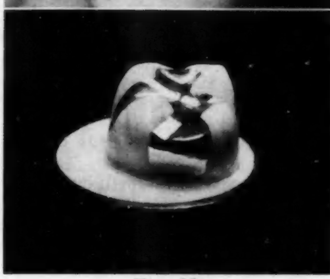


Fig. 28.

Fig. 29.

Fig. 26. The occlusal surface is made smooth with a rubber sulci disk. Note that the midget-headed mandrel allows greater surface coverage by the sulci disk.

Fig. 27. Formation of free mercury on the surface of an amalgam filling due to overheating during polishing. (Courtesy D. A. Keys, University of Nebraska College of Dentistry.)

Fig. 28. A completed restoration.

Fig. 29. Completed amalgam restorations in the mouth.

that has been breathed on. This frosted appearance is due to mercury that has been brought to the surface through overheating during polishing (Fig. 27).[68] If the disk increases the temperature of the tooth sufficiently to volatilize the mercury, the pulp is likewise endangered, and a hyperemic pulp will usually be the result.

Stubby amalgam polishing brushes and pumice are used by many dentists to obtain a velvet surface, but it is difficult to use these brushes under a stream of water, owing to the constant washing away of the pumice, and they can certainly overheat a filling very easily.

The desired smooth surface can be obtained in much less time with the rubber disks. The final polish, which is the least important step in the technique, may be achieved with precipitated chalk, tin oxide, or one of the commercial preparations for polishing amalgam fillings (Figs. 28 and 29). Separate handpieces are used for polishing to protect those used in cavity preparation.

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1729 Springhill Avenue
Mobile, Alabama

The Direct Self-curing Resin Restoration

Drexell A. Boyd, D.D.S.*

Since self-curing methyl methacrylate was introduced as an anterior restorative material, the clinician and the laboratory investigator have developed many different concepts and opinions regarding its efficacy in that role. Unfortunately, many of these opinions were expressed prior to the accumulation of sufficient information regarding this material and its usage, or they were conclusions drawn from inferences completely out of proportion to their actual significance. As a result many operators are in a quandary as to whether or not to use self-curing resin and, if they do, how to use it to produce satisfactory results.

First let us consider what constitutes the self-curing resins, what their properties are and how they may be handled. Such an understanding is essential if this material is to be used with reasonable success.

COMPOSITION AND PHYSICAL PROPERTIES OF THE SELF-CURING RESINS

Composition

In general, the self-curing resins now in use are of the methyl methacrylate group. The restorative is produced by bringing together the liquid (monomer) and a powder (polymer or already polymerized methyl methacrylate) to form a mixture of the desired consistency. This mixture is placed in the cavity preparation and after it has hardened (polymerized), it forms the restoration. Methyl methacrylate exists as a liquid monomer and as a polymer, a long chain molecular arrangement of the same proportion of chemical elements as the

From the Department of Operative Dentistry, Indiana University School of Dentistry, Indianapolis.

* Professor and Chairman, Department of Operative Dentistry, Indiana University School of Dentistry.

monomer. The polymer is a solid at normal temperatures. To speed polymerization of the liquid portion of the mixes, catalysts and accelerators have been added to the monomer and polymer.[1] These additives distinguish the self-cured resins from the so-called processed resins used in denture bases. In the processed resins, heat is used to polymerize the monomer content of the monomer-polymer mix.

Regardless of the process used in polymerization, the monomer undergoes a volumetric loss of approximately 20 per cent ("polymerization shrinkage"). Fortunately, the powder portion of the mixes used for restorations has already been polymerized and has already undergone this shrinkage; thus, only the monomer portion of the mixture undergoes shrinkage, which may vary from 2 to 10 per cent of the volume of material, depending upon the amount of monomer used to make the mix. This shrinkage has long been a point of contention among clinicians as well as laboratory investigators, for it was recognized that when used as a restorative, a material that would shrink this much would present a problem relative to its proper fitting and sealing of the cavity. As a result, all good techniques for the use of resins as a restorative attempt to use some method to counteract or compensate for the shrinkage of polymerization. All of the techniques mentioned here have as their basis procedures designed to limit the effects of shrinkage enough to insure the success of the restoration.

Benzoyl Peroxide Type. Of the two general types of methyl methacrylate self-curing resin now in use as a dental restoration, the first is known as a benzoyl peroxide resin. In this type benzoyl peroxide has been added to the powder or polymer and serves as the catalyst to induce polymerization of the monomer portion of the mix. The liquid, or monomer, contains a tertiary amine which acts as an accelerator to the catalyst (benzoyl peroxide) and speeds up its action in bringing about polymerization. This type of self-curing resin produces heat from the reaction of these agents when they are brought together in the mixing of the monomer and polymer. Most popular American-manufactured restorative resins are of this type. The principal difference of one from the other is the particle size of the polymer and the balance of the catalyst accelerator to fit or work with its respective plasticizing period.

Sulfinic Acid Activated Type. The second type of resin now in general use as a restorative is the sulfinic acid activated type, in which paratoluene sulfinic acid is the chemical agent or catalyst used to produce polymerization. Thyonyl chloride with dimethane is used as a hastener or accelerator and is in the liquid monomer. The paratoluene sulfinic acid catalyst is stored in an oil vehicle in a separate foil tube, for it is relatively unstable and must be "fresh" if proper results are

to be obtained. When this type of resin is used, the oil vehicle is blotted out of the catalyst and it is thoroughly blended into the monomer before the powder or polymer is added to form mixes for restorations. The monomer and catalyst will polymerize without the addition of a polymer and for this reason the material cannot be used with the "bead-brush" technique. However, thin fluid mixes may be made with it and a "brush-flow" application can be made if a non-pressure technique is desired. Sevriton, an imported product marketed by Amalgamated Dental Products Co. Limited, is the most popular brand of this type of restorative resin. This type of resin has the favorable quality of polymerizing much more rapidly than the benzoyl peroxide type; in fact, it may be trimmed and finished at the same sitting, a distinct advantage over the other type of resin.

Physical Properties

A working knowledge and an understanding of the general physical properties of the resins are necessary if the material is to be evaluated properly and used as a restorative.

The low solubility of resins in the fluids of the mouth (0.01 per cent) is one of the few good physical properties of the resins. From this quality alone it possesses after polymerization a potential for permanency in volume and form not equalled by any of the zinc phosphate or silicate cements. This quality, however, may work either to the advantage or disadvantage of the surrounding tooth substance. If properly adapted, contoured and retained, resin produces a restoration not subject to disintegration by solution and thus will maintain the anatomical form of the restored surface. However, if the resin restoration is loose, it will not dissolve and fracture away as cement and silicate and will present the potential danger of remaining in place even though loose from the cavity walls and retention. This latter condition is also observed under amalgam, foil and temporary stopping and usually leads to a softening of the tooth substance adjacent to the loose material.

The modulus of elasticity of the resins is roughly 300,000 pounds per square inch. When this is compared to that of gold, which is 14,000,000 pounds per square inch, it is readily recognizable that this quality is considerably lower than that of most restoratives. For this reason resins should not be used in areas where one of the main criteria for success is the ability of the restorative to withstand load and its subsequent stress and strain.

Hardness of the resins may range from 16 to 24 Knoop. The hardness of gold may vary from 60 to 200 Knoop according to its alloy

constituents; tooth enamel is around 300 Knoop. From this comparison it can be seen that the resins are relatively soft and for that reason should not be used where they will be subjected to heavy occlusal or incisal forces that produce wear or abrasive patterns.

Thermal conductivity of the resinous materials has been estimated as approximately $\frac{1}{140}$ that of the metal restoratives. Therefore the resins are good insulating media and do an excellent job of protecting the ends of the dentin tubules and the pulp from thermal irritation. This is particularly noticeable in the cervical area, which is often highly sensitive to thermal stimulation.[2]

The coefficient of expansion of the resins is 8×10^{-5} per degree centigrade, whereas that of tooth structure is 1×15^{-5} per degree centigrade. Roughly, this means that the resins have a coefficient of thermal expansion seven to eight times that of tooth substance. This great difference is responsible for the phenomenon called "marginal percolation" that has been observed around resin to a greater degree than that found around other restoratives with a lower coefficient.[3] The full meaning of this phenomenon is not yet fully understood by the laboratory investigator or clinician, for certain assumptions and observations under many varying conditions have resulted in confusing rather than clarifying the significance of this poor quality of the resins.

CONSIDERATIONS AND CAUTIONS RELATIVE TO THE USE OF RESINS

From the previous discussion it is apparent that the resins possess few outstanding physical properties as restoratives. Thus, if they are to be used intelligently and successfully, certain conditions and cautions should be observed and exercised. Primarily the use of the resins is indicated only when, at the time of insertion, high esthetic qualities are the main requisite. This would limit their use to class III, IV and V restorations. Unfortunately, their low modulus of elasticity and hardness preclude their use as a class IV restoration except in the very unusual instance. Inasmuch as the resins have little or no anticariogenic properties such as have been attributed to amalgam and silicate, they should not be used where there is high caries susceptibility and poor mouth hygiene.[4–6] Recently some manufacturers have considered the placement of anticariogenic agents in their resins and one company already has on the market such a product, but it is too new at this time for any evaluation of its effectiveness.

The polymerization shrinkage and coefficient of thermal expansion dictate that resin should be so used as to minimize these two conditions as they are related to the success of the restoration. Generally

speaking, this is best done by using application techniques that minimize the effect of polymerization shrinkage, that is, thin mixes that facilitate the formation of mechanical locks between the resin and tooth substance, and the use of adhesives or sealers to further facilitate the formation of such locks. Placement of resin in medium to small cavities and in areas not subject to extreme temperature change will do much toward limiting the maximum effect of thermal expansion and contraction of the resin.

The selection and use of one of the newer color-stable benzoyl peroxide resins or the sulfinic acid resins will greatly alleviate the problem of postoperative discoloration. These materials over the past three years have shown evidence of a discoloration factor no greater than that of the silicious cements. Needless to say, neither is perfect in this respect.

Adequate toilet of the cavity and the prevention of contamination are important because foreign material left on and along the walls will lead to subsequent discoloration and also inhibit the formation of mechanical locks which are essential for good adaptation. Moisture of any type not only prevents good adaptation of the resin but contaminates the resin so that eventually deleterious effects may be noted in the restoration. It has been reported and observed that moisture contamination affects the catalyst-accelerator reaction and the physical properties of the resin.[7,8] For these reasons resins should be used only with a properly placed dam or when adequate isolation free from any possible contamination can be obtained.

CAVITY PREPARATION FOR RESIN RESTORATIONS

Successful clinicians long have recognized that, no matter what restorative is used, the most important criterion for serviceable restorations is a cavity preparation which has sound mechanical and biologic qualities. This is even more true with resins, because of their low modulus of elasticity and low hardness. There are no short cuts or substandard preparations that may be used successfully with the resins. It is my opinion, having reviewed the cause of failures of restorations as reported by Healey and Phillips,[9] that many of the failures attributed to resins are due to improper cavity preparations. The restorative cannot and should not be blamed for inadequate cavity preparation if the dental profession is to be objective in its evaluation of the resins.

As has been pointed out before, the resins themselves possess no anticariogenic quality and for this reason as well as the standard conditions that dictate or control the outline form, it is imperative that

cavity walls and margins be extended to self-cleansing and protected areas.

The quality and extent of the resistance and retention form incorporated in the preparation have a great deal to do with the successful use of resins. Inasmuch as resins have a low modulus of elasticity, low hardness and a tendency to flow or abrade under load, it is essential that these qualities not be slighted. Cavity walls, floors and bases should be parallel and perpendicular to the basic loads and stresses to which the restoration and remaining tooth structure will be subjected. The enamel walls of the preparation, when they involve a curved surface, should be properly flared so as to be parallel to the enamel rods. This procedure, which is standard for all restoratives, will

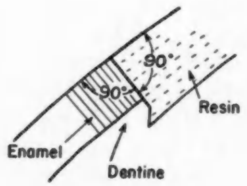


Fig. 1.

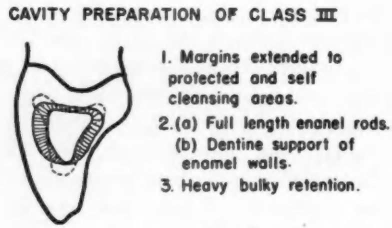


Fig. 2.

Fig. 1. Relationship of resin to the enamel wall for maximal resistance of the resin and enamel to stress.

Fig. 2. Desirable qualities of the preparation for a class III resin restoration.

insure a maximum bulk of resin at the margin and full support and strength of the enamel wall.

Figure 1 shows diagrammatically the proper relationship of the restorative resin and the enamel. A beveling of the cavosurface angle, a feather edge or thin areas of resin at the margins doom such regions of the restoration to almost 100 per cent failure if they are subjected to load or stress. Retention should be as bulky and heavy as is consistent with the remaining tooth structure and the conservation of pulp integrity. Providing bulk of material (resin) is the most practical way to compensate for the poor physical properties of the resins. Use of techniques that facilitate closer and better adaptation of resin to the cavity walls and retentive areas is also important in achieving optimal results.

When the process of caries removal has placed any portion of the axial or pulpal wall below the ideal or desired depth in the dentin, cement bases are advocated for mechanical as well as biologic reasons (see under *Postoperative Complaint,* p. 118).

Figure 2 is a class III preparation listing desirable qualities for a resin restoration.

FABRICATION OF THE RESTORATION (MANIPULATIVE PROCEDURES)

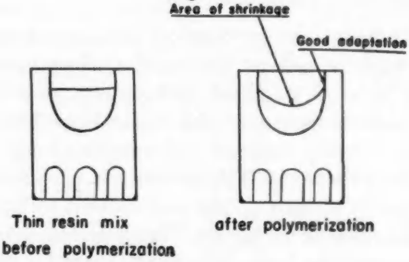
Pressure or Bulk Pack Technique

The so-called "pressure" or "bulk pack" method employs a plastic or metal strip type of matrix. This method, because of its simplicity and efficiency, is very practical and should give reasonably good results when properly executed. The basic principle is that of exerting pressure on the already inserted polymerizing resin by drawing the strip tightly about the resin. This pressure is supposed to force excess resin into the cavity to take up the void created by the polymerization shrinkage of the resin in the cavity. This principle is used in industrial plastic molding and has been successfully used by the prosthodontist in pressure or injection molding of prosthetic appliances. Unfortunately, in the operative procedure it is impossible to produce a mold which will confine the excess material and force it into the cavity. When using a strip matrix in a bulk or pressure technique, the excess fluid resin is forced to the outside of the cavity to form flash, and the pressure from the strip is then exerted upon the edges of the cavity and not upon the resin of the restoration.

Apparently, then, the good to fair results obtained from the "strip-pressure" technique are not due to confining pressure but to other factors, such as the pattern of contraction and the shape and form of the restoration produced by a properly shaped and adapted matrix. The pattern of polymerization contraction within the cavity, and not the volumetric loss of contraction per se is the key to successful adaptation of the resin for the pressure or bulk technique, or for any other technique with the resins. This phenomenon has been described by Nealon[10] and no doubt explains why fair to good margins may be obtained with this material even though there is some volumetric loss due to polymerization shrinkage. This phenomenon also explains the paradox observed by most operators: restorations made of thinner mixes that have (by the laws of polymerization) a greater volumetric loss have also better adaptation to the cavity walls, and better retention and margins. The reason is that the thinner mixes, which have a lower viscosity and surface tension, tend to flow into the fine crevices of the preparation and polymerize, forming mechanical locks which hold the resin in close apposition to the cavity wall during polymerization contraction. This causes a "pattern of contraction" to occur which

draws upon the material in the unconfined area of the restoration, which is usually the surface center of the volume of material making up the restoration. This phenomenon is illustrated in Figure 3, from which it can be seen that the apposition of the resin is not due to pressure but to the mechanical locks which hold it tightly to the walls of

Fig. 3.



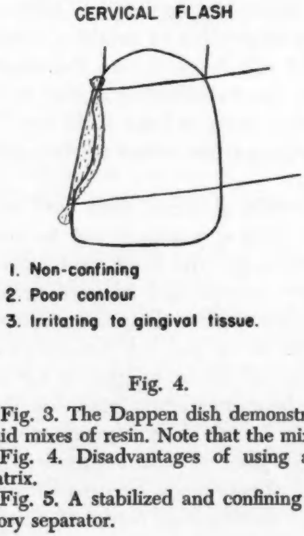


Fig. 4.

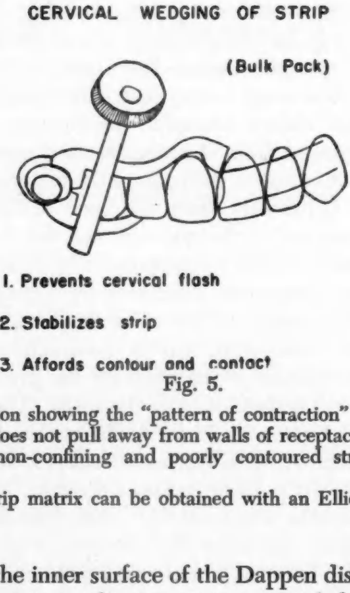


Fig. 5.

Fig. 3. The Dappen dish demonstration showing the "pattern of contraction" of fluid mixes of resin. Note that the mix does not pull away from walls of receptacle.

Fig. 4. Disadvantages of using a non-confining and poorly contoured strip matrix.

Fig. 5. A stabilized and confining strip matrix can be obtained with an Elliot-Ivory separator.

the cavity—in this illustration, to the inner surface of the Dappen dish. When using the pressure or bulk strip application, it is essential that there be a sufficient excess in the unconfined area to act as a reservoir from which the pattern of contraction may draw resin to fill up the void produced by polymerization contraction. Such excess material is also necessary for proper contour, contact and form of the restoration.

The use of so-called sealing primers or adhesives as now offered by most manufacturers will greatly facilitate the adaptation of resin to the cavity wall. They rely upon the same principle, low surface tension and the formation of mechanical locks, to hold the resin in apposition. These materials are basically monomers, and when they are polymerized by the catalysts and accelerators of the resin mix, they become part of the restorative. They also contain chemicals which some investigators claim will facilitate a closer adaptation to the organic and inorganic constituents of tooth substance.[7]

The strip bulk pack technique, because of its simplicity, is the most popular application method; however, if improperly used, it produces many undesirable effects in the quality of the restoration. Figure 4 illustrates the most commonly observed fault of an improperly adapted and secured strip matrix: a cervical overhang of excess material, termed "flash." Such material is most difficult to remove and often its removal results in destruction of the cervical seal and subsequent failure of the restoration. Failure to remove such material can also result in chronically inflamed gingival tissues and the associated sequelae. Another condition resulting from an improper strip technique is that of under-contour of the restoration, which results from the use of flat, uncontoured strips which do not reproduce the anatomic curvatures of the surfaces being restored. This inadequacy quite often is the cause of loose or open contacts. An unanchored or unstabilized strip which is subject to movement during polymerization will produce an open margin by pulling the resin away from the cavity walls before the material has set sufficiently to resist such forces. Strip movement usually will result in an open margin of the area of the restoration from which the movement starts, and a good margin at the area towards which the strip moved. Movement or slipping of the strip labially or lingually will result in a poor or open labial margin and a good lingual margin, or vice versa.

When properly contoured strips with cervical confining and stabilizing devices are used, these inadequacies can be almost completely eliminated. Figure 5 demonstrates the use of an Elliot separator with a convex contoured strip. Such a device, if properly adjusted below the cervical seat of the preparation, confines the resin and prevents the formation of cervical flash. This device and procedure will stabilize or hold the strip in such a manner that it will not move during polymerization, and it also affords a means of obtaining separation between the restoration and the approximating tooth. Some separation is essential because compensation for the thickness of the strip is necessary. There must also be a contoured excess of resin to serve as a reservoir and sufficient material for contour and contact.

The strip may be contoured by drawing it over a rounded surface or burnishing it on a pliable surface with a large ball burnisher. When these procedures are used for a controlled bulk pack technique, it is advisable to adjust the strip and separator prior to mixing the resin and applying sealers; this will assure proper adaptation of the equipment and lessen the need to hurry during the application period. In most cases the resin is applied from the lingual aspect and the lingual tail of the strip is closed first and the labial drawn last, thereby assuring complete filling of the cavity.

Non-pressure Technique

A relatively new development in the application of resin to form restorations is the so-called "non-pressure" technique. The principles involved in this method are those of adding resin to a previous application to fill in the area of polymerization contraction and the use of thin mixes or monomer application to facilitate the formation of mechanical locks to control the pattern of contraction. Terms used to describe the various types of non-pressure applications include "brush," "brush on," "bead," "beading," "flow," "neutralizing," "compensating" and "non-pressure." These terms are descriptive of the equipment, the method of applying or the objective of these techniques. Regardless of terminology or equipment, the two basic principles previously mentioned are responsible for the success that has been obtained with the non-pressure techniques.

Nealon Technique. The brush-bead or Nealon[10] technique is basically that of painting monomer on the cavity walls with a .00 sable brush and then carrying small "beads" of warmed polymer or powder on the tip of the same brush to the monomer-wet cavity. The bead is then touched to the monomer in the cavity to form a thin mix that is carried by surface tension out over and into the walls and retention of the preparation. This process is repeated until the restoration has been built to the desired form. The periods between bead applications may vary from 10 to 30 seconds, depending upon temperature, the size of the polymer powder and the desires or opinions of the operator. After the last addition is made, the restoration is covered with either heavy oils or tin foil to stop surface evaporation during the polymerization of the last addition. It is important to remember that this technique can be used only with a benzoyl peroxide resin and that the finishing should be done at a subsequent sitting.

Flow Technique. Another popular and efficient non-pressure method of applying either benzoyl peroxide or paratoluene resin is the so-

called "flow" or multiple increment or stratified technique. A thin to medium-thin mix of resin is prepared and carried to the cavity on a trimmed .00 sable brush and is touched to the base of the preparation and allowed to flow into the retention until approximately one-third of the preparation is filled. At 2 minute intervals a second and a third mix (a bit thicker but still fluid enough to flow, adapt and control) is flowed into the cavity until it is filled to the margins and humped slightly in the central area of the restoration. The latter procedure is to assure an excess of resin from which the pattern of contraction may draw to fill up the void produced by polymerization contraction. Covering the surface excess with oil or foil is again advocated until polymerization is complete, at which time the restoration may be finished. If a sulfinic acid type of resin has been used, it may be trimmed and

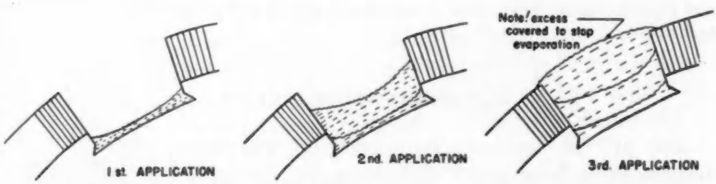


Fig. 6. Diagram of a three mix "flow" technique for a class V resin restoration.

finished at the same sitting if the minimum polymerization time (as recommended by the manufacturer) has elapsed.

This technique is represented diagrammatically in Figure 6, which shows a three mix application. In small preparations a two mix application usually is sufficient to form the restoration. Sealers or primers may be used with these two techniques by placing them on the cavity walls prior to the introduction of the resin. The non-pressure techniques are easily managed in class V cases and large open areas where excess may be controlled. In certain areas the pull of gravity on large amounts of the resin makes it very difficult to control the material and produce the desired form for the restoration.

Combination Non-pressure and Bulk Pack Technique. A combination technique may be used by a non-pressure application for the retention and the inner one-third of the restoration, and a bulk pack strip technique for the remainder to get efficiency, control and contour. Figure 7 shows such a procedure. The non-pressure technique assures good adaptation to the retention and the cavity walls; the bulk pack, if properly done, usually assures proper contour and contact with a minimum of time and effort.

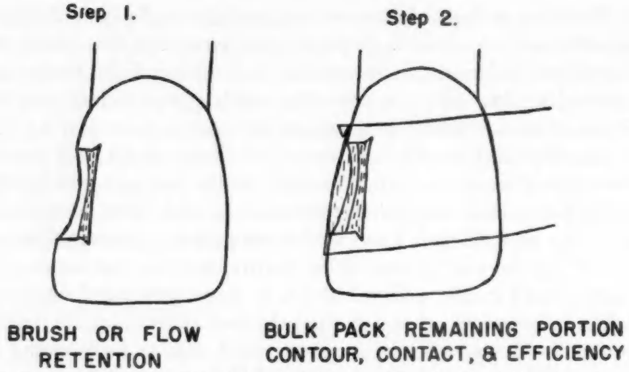


Fig. 7. A combination "flow" and "bulk pack" method of adapting resin for a class III restoration. This method has advantages of good adaptation and efficient application.

POSTOPERATIVE COMPLAINT

Many practitioners who have used the self-curing resins as a restorative have been concerned, from the theoretical as well as the practical aspect, about what effect this material and its chemical constituents have upon the dentin and the dental pulp. The information derived from histopathologic studies of dentinal and pulpal reaction to the use of the resins has been fairly consistent. In general, most studies indicate that the resins are relatively non-irritating.[11-14] The American Dental Association Council on Dental Research and Council on Dental Therapeutics pointed out that there was no evidence of permanent injury to the pulp that could be attributed to the resins.[15] However, many conscientious operators report adverse findings and are firm in their opinion that considerable damage to the pulp results from the use of resin.[16-17]

Observations as well as statistical study (by this clinician and his staff) of more than 20,000 self-curing resin restorations placed under reasonably good control (a dental school clinic) have led to the following conclusions regarding postoperative complaint:

1. Properly placed resin restorations have no greater degree of postoperative complaint and subsequent pulpal reaction than other restoratives when the resin has been used under similar circumstances.

2. All deep cavities should have an inert liner such as calcium hydroxide covered with an oxyphosphate of zinc cement base.

3. Most cases of postoperative complaint or of pulpal degeneration have been due to exposures of the recessional line of the pulp or to

other exposures where the restorations have been placed without adequate protection and allowance for repair or healing.

4. Resins will cause postoperative complaint, the same as any other restorative, when placed in teeth in which the pulp has already begun to degenerate. Such a practice is due to improper diagnosis and poor clinical judgment.

5. Loose resin restorations with fluid and the end products of food decomposition between them and the tooth substance are irritating to the ends of the dentin tubules and in turn to the pulp. This is true, however, of any loose restorative material. Proper adaptation and sealing techniques when using resin will eliminate this common source of sensitivity, pulpal degeneration and failure of the restorative procedure.

6. Thick dough mixes used with pressure techniques produce restorations with poor adaptation of the resin to the cavity walls and the inevitable increased incidence of postoperative complaint.

7. Proper protection for thin plates of dentin over the pulp, provided by the use of a rigid cement base, will help prevent strain and stress forces from producing irritation to the ends of the dentin tubules and compression of the pulp.

In general, it has been observed that the same conditions that produce postoperative difficulties when other types of restoratives have been used produce similar results with a resin restoration. Resin is not a panacea that can be substituted for proper operative procedures. The use of resins, because of some of their poor physical and manipulative qualities, necessitates careful and exacting operative procedures in order to produce satisfactory results for the patient and the operator. If the proper procedures are observed during adaptation and finish, the resin restoration should be as successful as any other if it has not been used beyond the limits of its physical properties.

DISCOLORATION

One of the objectionable characteristics of the resins has been that of their discoloration or darkening with the passage of time. This was particularly true of the early benzoyl peroxide resins before the development of the so-called "color stabilizers." The color change or tendency to darken has been attributed to a chemical reaction of the accelerator and catalyst.[7,18] Exposure of the polymerized restoration to ultraviolet and infra-red light produces a color change different from that produced by the chemical reaction of the accelerator and catalyst.[19] Caul and Schoonover demonstrated that both chemical and light exposure were factors in producing discoloration.[19] This study showed that

chemical discoloration is greatest during the first 24 hours but continues slowly for long periods of time, and that ultraviolet light exposure produces discoloration regardless of the age of the resin.

Clinically similar changes have been observed when using peroxide-amine resins. Apparently there is a discoloration that occurs shortly after the restoration is placed and continues indefinitely; this latter, however, may be at least partially attributed to the so-called "light" change. It has been observed that restorations placed in protruding and exposed areas have a greater tendency to discolor. As a precautionary procedure, the observance of the following points will help greatly in alleviating the discoloration problem when using resins:

1. Use a resin with a low discoloration index such as the new color-stable benzoyl peroxide type or a paratoluene sulfinic acid type.
2. Advise the patient of the discoloration problem and allow him to assume the responsibility for replacement if the esthetic qualities become objectionable.
3. Expose as little of the restoration to the labial surface as is consistent with extension for prevention and convenience.
4. Wherever possible, place the restoration below or above the lip line to reduce excessive exposure to light.
5. Use as little monomer as is possible to produce the desired working consistency.
6. Prevent contamination during insertion and polymerization. As has been mentioned before, foreign material will affect the physical properties of the resin by reducing the effectiveness of the accelerator-catalyst reaction and will leave debris which will become discolored.

Clinically, it has been observed that the paratoluene sulfinic acid resins have a relatively low discoloration index; for this reason, as well as for their manipulative advantages, they are being extensively used by the resin clinician.

FINISHING

Proper trimming and finishing of the resin restoration will contribute much to its success as well as to the maintenance of its esthetic qualities for a longer period of time. Void-free properly mixed resin with good apposition and smooth margins and surfaces will prevent the accumulation of debris and subsequent stain. If a properly controlled confining matrix technique has been used or the restoration has been adequately contoured with a non-pressure technique, the finishing operation is relatively simple. Once polymerization is complete, any excess is trimmed flush to the margin with suitable burs and stones. The rotational direction always must be from the resin to the enamel. A portion of the enamel plates involved should be used as a guide or

guard to prevent overtrimming. This is followed by a polishing with flour of pumice on a white rubber cup. Excessive glazing or glossing of the surface of the restoration should be avoided, for the body of the resin should absorb some light in order to prevent light reflection which will destroy the esthetic qualities of the resin.

ESTHETIC RESULTS

Figure 8*A* shows the lingual view of a class IV preparation with a reinforcing wire in place prior to the placement of the restoration.

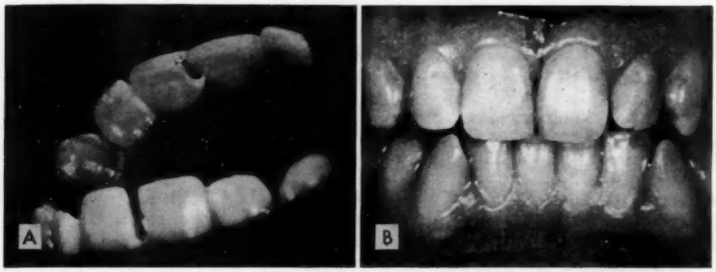


Fig. 8. *A*, Class IV preparation with reinforcing wire in place. *B*, Esthetic results of class IV restoration.

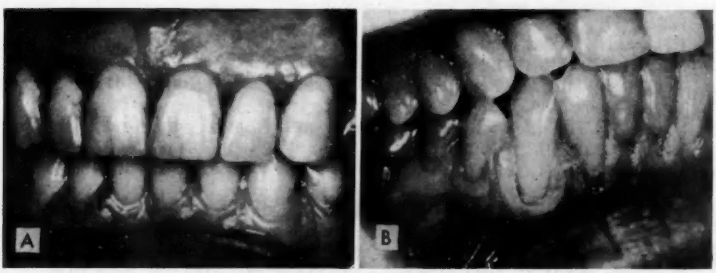


Fig. 9. *A*, Class V restoration made with "brush-bead" technique. *B*, Cervical erosion case treated with "flow" technique.

Figure 8*B* is a labial view of the finished restoration, which demonstrates the high esthetic qualities which may be obtained with resin. This case was one in which the esthetic demands of the patient were the primary factor in the selection of a restorative material. Figure 9*A* is an example of extensive cervical caries restored with a brush-bead technique. These restorations are well below the lip line so they should maintain their esthetic qualities indefinitely. Figure 9*B* is a case of cervical erosion in which pronounced hypersensitivity was present. The lower right lateral cuspid and first bicuspid have been restored

with resin using a "flow" technique. This photograph, made five years after the insertion of the restorative, demonstrates that discoloration even with an old non-color stable benzoyl peroxide resin is not too great if the material is not subjected to extensive exposure to light.

Figures 1 to 7 are from "Clinical Operative Dentistry," edited by W. J. Simon (Philadelphia, W. B. Saunders Co., 1956).

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1121 W. Michigan Street
Indianapolis, Indiana

Gold Foil in Everyday Practice

Bruce B. Smith, D.M.D.

Gold foil is a unique service. It is sterile and is placed in a freshly cut cavity directly from the flame. It has antibacterial action second only to that of copper cement and copper amalgam.[4] The finest margins in dentistry may be obtained with this material. It is honest, for an operation may be recognized as a success or a failure when the restoration is complete. It may serve in a tooth not only for 20 to 30 years, but for a lifetime.

Indications and contraindications much be recognized and understood, however, for success and intelligent use of foil in practice. With the possibility of using well fitting crowns, inlays, and other types of castings, it is a mistake to attempt to restore large carious areas with foil just as it is a mistake to cut an inlay cavity in a tooth with incipient caries and thereby destroy fine tooth structure, when a properly placed gold foil restoration will conserve and protect the patient's dental resources.

INDICATIONS AND CONTRAINDICATIONS

The salient indications and contraindications for gold foil are logical and self-evident. Extensive cavities or those with weakened walls which would place an unreasonable strain on the patient, the tooth, or the operator, should not be restored with gold foil. The very young patient whose root development is insufficient or whose periodontal membranes are too thick to properly resist malleting should not receive gold foil, nor should the individual with extensive aveolar bone recession.

Devital teeth may receive foil just as they may of necessity be forced to assist at times in supporting a bridge, but it is far better to avoid any unnecessary strain on a tooth with a weakened circulatory protective system.

Finally, in rare instances, one will contact a patient whose temperament is unsuited to the malleting. Such a person will be intolerant of

the mallet blows. By far the majority of patients, however, will relax while the cavity is prepared and filled.

Class V Cavities. Gold foil may be used satisfactorily in almost all normal restorative procedures if the operator is competently trained in the art. The prime indications for the average man will first be found in class V cavities. There the fine finish without overhang, ditching, or scratches, will permit the original tissue to come up around the foil and usually cover at least the gingival third of the restoration. No expansion or contraction will cause gingival irritation, nor will cement margins or cement deterioration cause unsightly stains or recurrent caries. Neither will the entire filling wash away as with siliceous cements, leaving a sharp cavity margin to cut the gingival tissue.

Class I Cavities. The pit and fissure cavities are second in indicated foil usage. Here we find notably simple operations where foil may be placed rapidly and neatly. Class I foils in molars and bicuspids and the lingual pits of the maxillary incisors become more dense through wear and abrasion and do not have the lack of edge strength noticeable in some alloy occlusal restorations. The foil tends to burnish with usage.

It is common practice in many areas to place a simple foil restoration in the mesiobuccal aspect of a gold crown. This class I cavity is cut as a tiny opening in the crown just prior to cementation in order to release the hydraulic pressure of the cement and to allow the well fitting crown to seat completely. When cementation is accomplished, the opening is cleaned and made retentive. Then in minutes the pit is restored with gold foil. Because of the accessibility, fine cuttle disks may be used in the finishing, and the operation is complete.

Class III Cavities. In many areas, foil is in great demand for class III cavities. What could be finer on the distal aspect of a cuspid where strength of contact is essential for the keystone of the dental arch? The distal aspects of central and lateral incisors are again natural areas for foil because they are very inconspicuous in most mouths when properly prepared, giving the patient unparalleled service and freedom of recurrent decay. Condensed properly, they do not absorb oral secretions. Neither do they shrink from cavity walls when exposed to the air.

The lower incisors are small, delicate teeth, in which only one or two additional replacements will jeopardize the incisal angle of a tooth. Therefore, foil restorations are ideal by virtue of their neatness and tiny proportions (they may be unusually restricted with safety in this area) and because they do not require repeated preparation over the years.

Class II Cavities. The class II foil restoration, generally speaking, is

for the more experienced operator. Its indications are many. Esthetically, it is far superior to an inlay. Therefore, on any mesial bicuspid or molar surface it is the material of choice. The lower first bicuspid is a special indication, for the strong lingual triangular ridge of the buccal cusp cuts the tooth into two separate areas, each of which is too delicate to permit inlay cavities without extensive and wasteful loss of vital tooth structure. Occasionally on the other bicuspids, where disto-occlusal restorations are already present, foil may be placed in a mesio-occlusal cavity and readily joined to the distal inlay or foil. This has the obvious advantage of retaining a pre-existing sound restoration for the patient and supplying the most esthetic and permanent service possible.

Class VI Cavities. Class VI abrasion cavities are often overlooked, but restoration may serve to substantially delay later bite-opening procedures and avoid broken teeth and many of the effects of wear on an older patient's dentition. It is well to consider these cavities in geriodontics, and platinum and gold foil is the finest restorative material possible to correct the situation. The added hardness of the gold foil with platinum produces fine wearing qualities without enough additional working harshness to be noticed by the operator.

OFFICE PREPARATION OF GOLD FOIL

The preparation of gold foil for use in the office is a simple, direct procedure which the assistant may learn quickly. Normally a book of No. 4 foil, non-cohesive, is cut into the proper sizes for either pellets or cylinders (see Fig. 1). This is best done by measuring the size of the gold sheets within the book; then a piece of cardboard of the same size is cut out and marked with pencil into the proper divisions. The cardboard sheet is placed over the tissue, directly in line with the underlying foil sheet. Now the pencil markings of the correct size are transferred from the edge of the cardboard to the tissue paper. Once the tissue is ruled off into the size squares desired, it is convenient to slip four paper clips over the edges of the entire book (one at each corner) to prevent any movement of the foil or tissue while cutting. The entire book or sections of it may now be cut with shears into the proper size sheets. The pellets used most often are $\frac{1}{64}$ and $\frac{1}{32}$ of a 4 grain sheet. The $\frac{1}{128}$ is used less often, as is the very large $\frac{1}{16}$ pellet.

To convert the small sheets into pellets the assistant, having clean, dry hands, carefully picks up the sheet with a pair of light flat dental pliers. Resting the sheet delicately on the first two fingers and thumb, the corners of the sheet are tucked in and with a quick, light rolling movement the sheet is made into a small round ball. (Some prefer a

football shape.) Care must be taken not to exert too much pressure, as the pellet should be uniform in density and free of hardness so that it may flow evenly and easily under the condenser point.

The non-cohesive cylinders are fashioned by placing the small sheets on a clean folded towel. Then the two outer edges of the long sides are folded inward by marking the gold with a straight edge and pressing it down with the towel. The folding is continued until a uniform strip is made which is twice the approximate depth of a class V

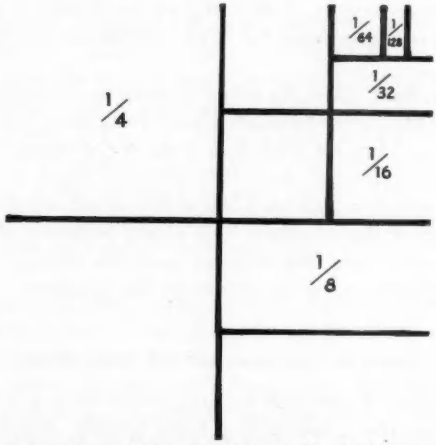

Fig. 1. The divisions into which a No. 4 book of gold foil may be cut for convenient preparation of pellets and cylinders.

cavity or $1\frac{1}{2}$ times the width of the proximal walls of a class II cavity (depending upon the type of cavity in which the cylinder is to be used). The strip is now picked up at one end by a small two-pronged fork or a jeweler's broach. A large mounted tapestry needle, size 22, with the end of the eye cut open, may also be conveniently used for this purpose (Fig. 2). By laying the strip on the outer edge of the palm of the hand and rolling the fork along the strip, a cylinder is formed which has a small hole in the center. The cylinder is slipped off of the fork and, while held firmly between the thumb and forefinger, the ends are slightly and evenly crimped with the flat dental pliers to prevent the cylinder from unrolling. The cylinders most often used are the $\frac{1}{16}$, $\frac{1}{8}$, and $\frac{1}{4}$ sizes. Occasionally a $\frac{1}{2}$ or a $\frac{1}{32}$ cylinder is very convenient.

When the cylinders are later flattened to lie against a cavity wall, the center hole prevents the formation of a knot or bulge in the center

of the cylinder. This type of cylinder is always used in a non-cohesive state and is never annealed. This allows the layers of gold to slide one upon the other against the cavity walls and secure the finest marginal adaptation.[1]

However, being soft foil, the cylinders are not able to stand pressures or heavy strains, and are best suited to line labial or buccal cavities, the proximals of class II cavities gingivally from the contact point, or in adding bulk to the pulpal walls of small but deeper

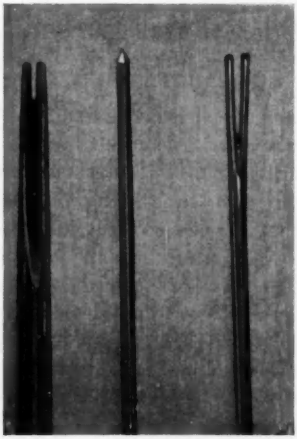

Fig. 2.

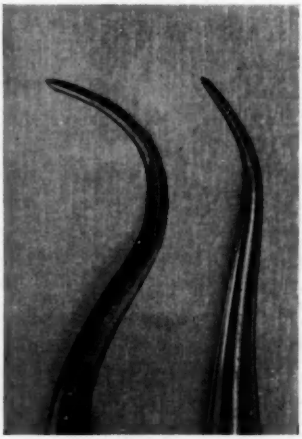

Fig. 3.

Fig. 2. Instruments for rolling cylinders. From left to right: a fork prepared from a dental instrument; jeweler's broach; No. 22 tapestry needle with end cut open (mounted on a peg-wood stick).

Fig. 3. Holding instruments for assisting in foil placement and stabilizing of the first portions of the restoration.

cavities. When not subject to excessive wear, fine class I restorations may be fabricated with these cylinders.

The pellets may be annealed in an electric annealer, in a mica tray over an alcohol lamp, or piece by piece by the assistant in a clear, blue alcohol flame. When the annealing is done in an open flame, the pellet should be held on a thin iridioplatinum or tungsten wire and heated to a dull red only. The wire in a large light bulb may be conveniently used for this purpose.

Great care should be taken that the gold is stored in an atmosphere of ammonia to prevent contamination by other gases. Cotton pledgets saturated with ammonia are placed in the storage bottles of rolled gold as well as in the gold box. Phosphoric acid fumes from matches,

medicament fumes, and hydrogen sulfide breakdown odors, are all potentially dangerous to the cohesive properties of the gold.

CONDENSATION

Every operator finds that a correctly shaped instrument to use as a condenser assistant is invaluable to stabilize the first pellets and to properly locate the later ones (Fig. 3). The common use of a second condenser for this purpose is a mistake, for the point is bulky and the shaft end is confusing to the chairside assistant.

To expedite all procedures, the chairside assistant and the operator must function as a well trained team. Even though the pneumatic condenser is a great aid in cavities of difficult access, and an electromatic condenser properly regulated may be of use, the hand mallet is still the backbone of all practical study club and office procedures. It is extremely fast, versatile, and dependable. The assistant should master a "one, two" blow which is timed to coordinate with the operator's pressure on the condenser. In this manner the tooth is set to receive the blow, and the periodontal membrane is condensed on the side where the impact will be met. The first tap seats the condenser and the second condenses the gold. The blows should be uniform and as regular as a clock. They must be of at least 15 pounds pressure on a 1 mm. diameter condenser, to secure adequate condensation, and should be delivered at a right-angle to the condenser shaft without tapping or tilting the head of the mallet. After the two blows the condenser point is stepped over one-half of its diameter so that each imprint is one-half covered by the next. Each succeeding row of imprints is set over so that the new imprint covers a quarter of two marks in the preceding row, much like shingles on a roof.

The smaller the pellet and the smaller the condenser point used, the finer the result. A straight round condenser with a 0.5 mm. face is the ideal size for the best condensation and efficient work in the routine building of foil, though other sizes and shapes have definite uses which will be considered later.

A straight condenser should be used whenever possible, for the pressure is more directly transferred from mallet to gold. The old rule applies that whenever the diameter of a condenser point is doubled, the area of the condenser point and the pounds of force required to adequately condense the gold are four times greater. Many of the technical procedures to follow are based on the work of W. I. Ferrier and the training employed in the Northwest Associated Gold Foil Study Clubs. Great credit is due these instructors for their continued advancement of fine dentistry.

DETAILS OF CAVITY PREPARATION

Class I Cavity Preparation

Outline. The outline should be conservative, for it corrects faults in enamel only. The entire area is washed by food excursions. The outline should correspond to a class II occlusal outline in anticipation of later proximal involvement.

Retention. Resistance and retention are cut principally with short 700 series burs (one-third is broken off and the end is squared on a wheel stone). All marginal ridges should be supported by dentin and have slightly divergent walls. The only retentive points are at the expense of the thick buccal and lingual walls at the mesial and distal aspects to assist in starting the foil. They are made with small gingival margin trimmers (Nos. 28 and 29).

Finish. Fine planing is done with hoes on the pulpal wall (Nos. 22 or 20 of the Ferrier Study Club set). The other walls are planed with a Wedelstaedt chisel or the side of a hoe. All final planing should be done with very sharp instruments. No bevel is added as such, but the final planing introduces a slight bevel automatically. A wall against which non-cohesive gold is to be placed should be free of any intentional bevel.

Foil Placement. There are three methods which may be employed in fabricating the restoration.

The method of choice for a relatively inexperienced operator is to use all cohesive gold, usually pellets of about $\frac{1}{32}$ to $\frac{1}{64}$ in size. The straightest possible condensers should be used that will give the proper angle of force. The first pellets of gold are placed at the extreme distal portion of the cavity and subsequent pellets are added and condensed so that the filling forms a concave contour both buccolingually and mesiodistally. The mesial wall is the area where greatest care should be exercised to insure an angle of force which will adequately adapt the foil to the wall. A condenser angle of about 12 degrees to a wall is generally considered to be the most effective. However, at times a slightly more parallel position is effective while exerting a wedging action against the wall and back pressure into the main mass of gold. A 90 degree angle to a wall or the other extreme, that of a position parallel to a wall, are both very poor practice and will almost certainly result in poor adaptation.

The second foil placement method is to line the periphery of the cavity with non-cohesive cylinders (rolled end out), using the No. 13 and No. 14 large parallelogram condensers. Each cylinder protrudes

one-third its length from the cavity and is tightly pressed against the walls. Large $\frac{1}{16}$ pellets are annealed and packed against the pulpal floor to stabilize the cylinders, and the remainder of the cavity is filled progressively as before with cohesive foil.

The foil should be built to contour, condensed carefully and finally burnished. Final contouring and margin trimming of the gold may be done with either a large round bur or a shortened and squared-off 701 bur, which is moistened to prevent the gold from "leading" the bur. A No. 1 or No. ½ bur may be used to smooth the sulci. Graded abrasive disks and powders complete the operation.

The third method requires the greatest skill but is very rapid. The restoration is made completely of non-cohesive cylinders. First, the periphery is lined as before. Then additional cylinders are forced into the cavity until it is tightly packed. Now, using a wedge-shaped instrument, the gold is forced apart laterally and one or two more cylinders are inserted if at all possible. Vertical condensation is now started, using larger condensers and working down to the 0.5 mm. size as the hardness increases. The final finish is secured with burnishers.[5]

Class II Cavity Preparation

Outline. The occlusal outline is not overly wide, with a small and neatly cut dovetail. It presents a slight reverse curve at the bucco-proximal area and the linguo-occlusal aspect is almost straight, depending upon the extent of lingual embrasure.

The proximal outline is cut with adequate gingival extension buccolingually. The lingual proximal outline forms an acute angle in the maxillary arch with the gingival wall, for less extension is needed occlusally due to the widening linguo-occlusal embrasure. The bucco-proximal outline is almost at right angles to the gingival wall for proper extension. In the mandibular arch these angles are reversed owing to the change in embrasure form. The major exception is the mesial aspect of the lower first bicuspid, for the lower cuspid form allows both gingival angles to be more acute.

Resistance Retention. Contrary to usual belief, the class II occlusal area is not simply undercut with an inverted cone bur. A 700 series bur will give the proper inclination and slight divergence needed for the isthmus area. It will also provide a slightly divergent and strong wall at the marginal ridge. The occlusal dovetail is slight but adequate to prevent proximal displacement. In the distal portion of the occlusal area a slight retentive or undercut area is made at the expense of the buccal and the lingual walls. This aids in starting the foil.

The proximal walls should be well boxed to the gingival wall, and actual retentive areas are seldom necessary. J. M. Prime claimed that these retentive areas, when present, were seldom if ever filled with foil. However, to disprove or to check Prime's findings, W. H. Gyllenberg, of Longview, Washington, readily demonstrated the entry of foil into these areas by the use of transparent teeth suspended in water.*

Finish. The walls are planed with sharp enamel hatchets or binangle chisels (Nos. 15 and 16 or 11 and 12 of the Ferrier Study Club set). Frequently the No. 40 or No. 41 modified Woodbury chisel will be found excellent for boxing and squaring the axial wall. The gingival should receive no bevel but be planed until smooth and even, for soft foil will rest against this wall.

Foil Placement. The placement of foil in a class II cavity may be skillfully done in a matter of 20 to 30 minutes. A matrix band never has a place in this technique. The proximal extension buccolingually should be minimal, adequate for the cleansing of the restoration yet narrow enough to allow the adjacent tooth to assist in supporting the foil as the proximal restoration is built.

Normally three cylinders of non-cohesive foil are placed in the proximal portion. The most common area of failure is at the buccogingival or linguogingival angle. Therefore, the two smaller cylinders are placed first and flattened firmly against each proximal wall (usually $\frac{1}{8}$ size cylinders in bicuspids) with the No. 13 and/or No. 14 parallelogram condensers. The instruments first force the foil gingivally and then laterally until a slight excess protrudes in both directions. The third cylinder, often $\frac{1}{4}$ size, is pinched into a wedge shape with the dental pliers and seated firmly between the two previous cylinders. After heavy packing with hand pressure, the square bayonet No. 18 condenser is used with a continuous, firm type of blow by the assistant. Care should be taken to condense the foil well along each proximal wall. When condensed, the soft foil should cover about two-thirds of the axial wall. If this is not the case, additional cylinders may be placed flat on top of the previous ones until the correct height is obtained. Condensing pressures and the angle of force should be directed into the cavity.

The cohesive foil is started in the linguo-axial line angle and usually $\frac{1}{32}$ pellets are used for the entire procedure. The foil is built up along the lingual wall and out to the adjacent tooth, tapering out as it reaches the buccal wall. When the pulpal height is reached on the lingual wall, the distal side of the occlusal portion is started, the gold

* Table Clinic, University of Oregon Alumni Meeting, 1950.

running forward to connect to the proximal restoration along the linguopulpal line angle. After the lingual walls are covered to the cavity margins, the line of force is changed and the buccal walls are gradually covered in the same manner. This leaves a saucer-shaped central area which is filled in and built to proper contour. The gold must be firmly condensed as the interproximal restoration grows, especially so against the adjacent tooth for contact and the cavity walls for adaptation. Lastly, the Nos. 16 and 17 interproximal foot condensers are employed to condense the gold from the contact point gingivally. Used properly they sweep the gold in toward the cavity from the adjacent tooth and pinch it off at the gingival margin. They may also condense the gold all along the buccal and lingual margins. The No. 12 or the Special F condenser may also aid in this respect. It is well to have adequate gold protruding from each buccal and lingual margin, for it is almost impossible to add to those areas after the restoration is completed.

The class II restoration may be finished quickly and well if a sound routine is employed. All excess gingival gold and interproximal gold should be condensed laterally toward the cavity and pinched off or shaved away. Well balanced gold knives, designed by Nathan H. Smith and used by study club men for over 30 years, are very helpful in this area. The excess gold on the buccal and lingual walls is reduced with a file and disked away, and the occlusal surface is contoured with a wet short 700 or 701 bur, being finally contoured with a sharp small discoid or cleoid. Most of the occlusal finish is then completed with graded disks and abrasives.

When all other areas except the contact point are essentially completed, the separator is placed and well blocked with compound. It should remain in place for only a short period of time. Usually the No. 4 Ferrier separator is the correct size for bicuspid and molar class II restorations. When a slight separation is achieved, the Gordon-White saw is pressed through the contact area and extra-long finishing strips quickly bring the gold to contour. The gold knife or sharp small cleoid carve and round out the occlusal embrasure. This is further smoothed and contoured with a large ⅞ fine cuttle disk, which easily by-passes the separator frame. The separator is immediately removed and, with the employment of abrasive powders and polish, the restoration is complete.

Class III Cavity Preparation

Outline. The classic class III outline blends with the adjacent lobe of the tooth, depending upon the shape and size of the tooth and its

position in the arch. With lapped or rotated teeth a variation may be found that involves a lingual approach or even a labial outline which follows the line of the adjacent tooth. But the variations will not be considered here.[2]

Forming the Cavity. Only six instruments are needed to form the normal class III cavity. They are the contra-bevel Wedelstaedt chisel, for the outline; the No. 23 hoe (6½-2½-9) for the interior; a pair of small angle formers for the labio-axio-gingival and linguo-axio-gingival point angles; the 3-2-28 hatchet for the incisal retention; and the No. 25 (4½-1½-25) hoe for the labio-axial line angle.

When caries undermines the enamel slightly, the cavity may be opened with the No. 23 hoe, but in cases of incipient decay the use of a chisel or hoe will sometimes start a fine crack or check running either incisally between the labial and lingual enamel plates or gingivally when near the cervical line. It is far better to use a small bur to open this type of cavity.

After the cavity is opened, a No. 33½ bur in the straight handpiece is used to establish the straight gingival wall. Then the bur is brought in from the lingual aspect and the gingival wall is accentuated here to form the so-called "linguogingival shoulder." W. I. Ferrier, to whom so much credit is due for his work in establishing fine gold foil procedures, has often said that this shoulder is one of the most important features in the entire technique, for the linguogingival area is where most class III foils fail if improperly done.

The gingival wall is cut straight and at right angles to the long axis of the tooth, the interior sloping slightly and forming an acute angle with the axial wall. The labio-axio-gingival and linguo-axio-gingival point angles are made at the expense of the lingual and labial walls and do not run axially unless forced to do so by the extent of the cavity and the contour of the tooth. These point angles run out and become the labio-axial and linguo-axial line angles about one-third of the way up the axial wall. Here the internal portion of the cavity is designed to give strength to the walls and lingual ridge areas. The middle one-third of the internal labial wall and lingual wall actually form a slightly obtuse angle with the axial wall. In the incisal one-third the angles become more and more acute until they run into the incisal retention, which frequently is located just a trifle to the labial side because there is more bulk of tooth structure in this area.

A common error is to leave too much "stock" or thickness in the middle to incisal thirds of the labial wall. This mistake can prevent easy access of the condensers and greatly hinder foil placement and condensation. The No. 25 hoe or the side of the No. 23 hoe can be used to correct this fault. The easiest method for testing, to be sure

there will be no difficulty, is to place the foil condenser into the prepared cavity before starting the gold. The small bayonet (No. 8) should reach all of the interior along the axiolabial angle with ease.

Foil Placement. Foil placement is started using $\frac{1}{64}$ pellets of No. 4 foil. Usually the No. 7 condenser, a long Carlson type with a round 0.4 mm. point, is the one of choice. The first pellets are placed in the linguo-axio-gingival point angle and more are added until the cavosurface angle is covered. It is wise to insure complete coverage of the linguogingival shoulder at this time, as later additions are sometimes difficult. Therefore pellets are forced through from the labial to the lingual side where they are condensed from the lingual in an axiogingival direction.

Gold is now added progressively across the gingival line angle to the labial retention area and secured there. This stabilizes the restoration and succeeding pellets are added to build up the lingual wall almost to the incisal retention.

At this point $\frac{1}{128}$ pellets are condensed by hand pressure into the incisal retention, using the No. 11 right-angle hand condenser. This gold is built down the linguo-axial line angle and connected to the previous mass. The operator should bear in mind that most retention is secured between the incisal and the gingival areas, and that care should be exercised in joining the two masses to insure that wedging action is established and that the sections are not dislodged. Frequently the tiny F foot condenser is a great aid in this area, followed by the No. 8 small bayonet in the incisal area. The last area to be filled is the middle third of the labial. When this is accomplished it is well to go over the entire restoration with the F condenser for "after-condensation."

The No. 1 or No. 2 Ferrier separators are most frequently used on class III restorations; occasionally the No. 3 is used in the cuspid area. They may be applied passively when the operation is started and turned up a little when the gold is being placed for the contact area. Normal caution should be exercised in their use because they continue to work over a period of time, and excessive separation may result if the pressure is allowed to act for too long a period. Many experienced operators prefer to place the separator after the foil has been condensed, for with their skill in placing and working the foil they will wedge separation enough for a proper contact.

It is well to use push files on the lingual aspect and pull files on the labial aspect. They should be worked carefully over the restoration and will tend to harden and burnish the gold. Finger stones or round burs may adequately reduce the lingual surface but are potentially dangerous from the standpoint of producing poor contour or shattered

enamel rods. Disks work well and rapidly but can produce flat spots or facets if they are not used lightly and moved continually. After the files, a sharp gold knife (No. 52 University of Washington set B) may be used to shave away the gold at the gingival margin. Now, extra-long finishing strips of graded abrasive grits will quickly bring the restoration to form. The extra-fine, extra-narrow* strips, when worn smooth, will leave a beautiful satin finish and complete the operation.

Class V Cavity Preparation

The class V is by far the most popular foil restoration in dentistry. The late E. M. Jones[3] has covered many of its variations, but the

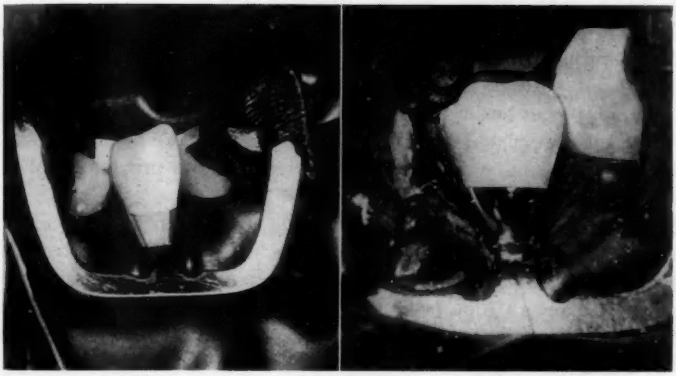

Fig. 4. Fig. 5.

Fig. 4. Class V cavity preparation with normal use of compound to stabilize the 212 clamp. Note the strength of the mesial and distal walls, which are flat and slightly divergent to the axial.

Fig. 5. Completed class V restoration, demonstrating the fine gingival finish without "ditch" or overhang. The lingual compound support is only necessary in unusually large cases or those needing extra periodontal support.

classic form is just now coming into universal use throughout the nation.

Outline. The outline is trapezoidal with the occlusal and gingival walls parallel to each other (Figs. 4 and 5). The occlusal wall should be parallel to the occlusal plane of the teeth so that restorations in adjacent teeth may follow the same guide and give an over-all pleasing effect of a well cared-for mouth. The proximal walls lie at the angles of the tooth where they are covered by the gingival tissue when the dam and clamp are removed.

* Moyco, J. Bird Moyer Co.

Retention. The retention is gained between the occlusal and gingival walls, with the gingival being the most retentive. If the occlusal wall is undercut to any extent, the gold may show through the overlying enamel and give a poor appearance. The mesial and distal walls are divergent to the axial wall for strength. All walls are cut easily, using a No. 34 or No. 35 inverted cone bur on its end for the gingival, mesial and distal walls, and on its side for the occlusal.

Finish. The No. 23 hoe (6½-2½-9) is convenient for finishing and planing the walls, but a large Wedelstaedt or straight chisel such as Jefferies No. 103 is very useful to straighten the walls and to plane the axial. A well planed axial wall is the sign of a good operator who takes pride in his work. A rough axial has no beneficial effect upon retention, and demonstrates a tendency to be careless.

Foil Placement. It is essential always to block the No. 212 Ferrier clamp carefully with modeling compound before starting the class V operation. A wise and very stable method is to place two very small compound pieces around and into the embrasures over which the bows of the clamp will rest. When these are cool, the clamp is seated, and two additional pieces attach the clamp to the previously placed compound.

Non-cohesive foil cylinders, usually $\frac{1}{16}$ in size, are used to line all walls of the class V cavity. They give finer adaptation, rapidity in filling the cavity, and ease in finishing. They also protect the margins against inadvertent blows of the condenser. The cylinders are placed end-on into the cavity with the two large parallelogram condensers, Nos. 13 and 14. Practically, it is best to line the mesial and distal walls first, then the gingival, and lastly the occlusal. A large $\frac{1}{16}$ or $\frac{1}{32}$ pellet of cohesive foil is now packed firmly across the entire axial wall and helps to stabilize the cylinders. With subsequent pellets, usually $\frac{1}{64}$, the restoration is built up in a concave fashion until the walls are covered. As the cohesive gold reaches the cavosurface area, the operator pinches off the excess of non-cohesive gold and covers the entire filling surface with cohesive foil, building to contour, which in the final finish should duplicate the normal curve of the enamel at the cemento-enamel junction.

The condenser used during the operation is the straight 0.5 mm. round condenser. Sometimes a No. 8 bayonet will assist in difficult areas where the clamp bow may interfere or where the proper line of force to the occlusal wall is a problem. The No. 5 Varney condenser or the smaller No. 12 foot condenser are very fine for the final contouring of the filling, for "after-condensation," and for pinching off the excess gold around all of the margins.

The entire restoration is now carefully and quickly reduced to the

proper contour with thin files of both the push and the pull type. These files should be thin enough to have a slight spring when used; when their work is done, only the finest disks and polishing agents should be necessary to lightly finish the restoration. Occasionally a fine line of gold may be found in excess at the gingival margin, and here special care must be taken in its removal. A very small Whiteside scaler, a Wedelstaedt chisel, or a Jones knife may be used to lightly trim the excess away. No instrument or abrasive should ever be allowed to contact or "ditch" the cementum, as overindustrious finishing here may result in a very sensitive area for the patient and poor adaptation of the gingival tissue.

Within a day, at the most 48 hours, the tissue will be beautifully molded over the gingival third of a well contoured and finished class V restoration. The satisfaction of the patient and the operator will continue to grow as decades pass. This fine material, the best available in operative dentistry, will continue to serve faithfully and honestly, rendering a true service to humanity.

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812 Cobb Building
Seattle 1, Washington

Hydrocolloid Techniques in the Fabrication of Inlays by the Indirect Method

FREDRICK A. HOHLT, D.D.S.

The perfection and use of the hydrocolloid techniques has been a major contribution to the ever-increasing popularity of the indirect method of "quadrant dentistry." Neither the ease with which they may be used nor their accuracy can be questioned. However, as with all dental materials, success is dependent upon a basic knowledge of their inherent physical and chemical properties and a proper manipulation of the material. Although there are various ramifications of the so-called hydrocolloid technique, all procedures must adhere to certain basic principles. The fundamentals cannot be altered to serve particular techniques. It is with these essential factors that this chapter will be concerned.

The reversible hydrocolloids of today are 80 per cent water, 18 per cent agar agar, and 2 per cent miscellaneous substances.[4,17] These hydrocolloids are colloids with water as the dispersion medium. All are gel structures in which the water is held by capillary action. When a gel may be passed into a colloidal solution by the application of heat and then may be reformed by chilling with room temperature water, the hydrocolloid is termed "reversible."

The irreversible hydrocolloids are different, because this colloid solution is changed to a gel by a chemical reaction, usually between potassium or sodium alginate and calcium sulfate. The set impression is not, of course, thermally reversible as are the agar-base materials. These dental irreversible hydrocolloids are commonly known as alginates.

REVERSIBLE (AGAR) HYDROCOLLOIDS

The recommended armamentarium for the use of reversible hydrocolloid in general dental practice, whatever type it may be, should

From the Department of Operative Dentistry, Indiana University School of Dentistry, Indianapolis.

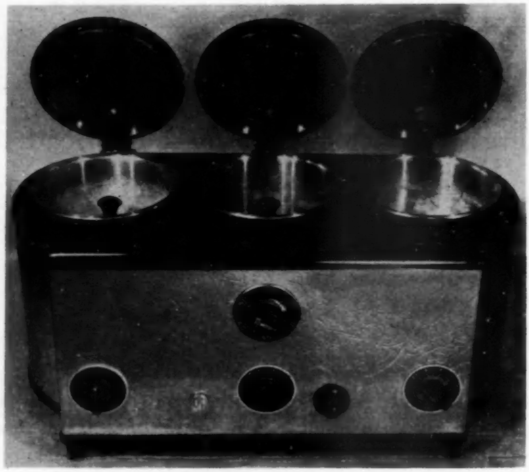


Fig. 1.

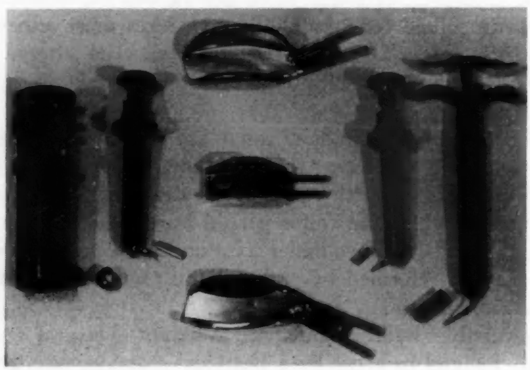


Fig. 2.

always be in readiness, and in the operative room. It should include (1) a conditioner with thermostatically controlled water baths containing liquefying, storage and tempering baths (Fig. 1); (2) small syringes for injecting the material into the cavity preparation, with 19 and 23 gauge needles, and water-cooled impression trays (Fig. 2).

At the beginning of each day the syringes and tubes of hydrocolloid are liquefied by boiling at 212° F. The minimum boiling time should be 10 to 12 minutes, although longer boiling has no deleterious effect.[10] If the material is allowed to set and must be liquefied a second or third time, a longer boiling time will be required. In order to bring

the gel into a sol condition, add 3 minutes or more each time the material is re-boiled. The water level should be such that the syringes will be immersed up to the top of the barrel, and the tube should be placed with the opening down and covered by the water to its base. After boiling, the syringes and tubes are transferred to the storage bath for a minimum of 12 minutes. If the material is maintained at a temperature between 145° and 155° F., the hydrocolloid may be stored for the entire day with no gelation taking place. The conditioning unit should be checked routinely for inaccuracies in the tempera-

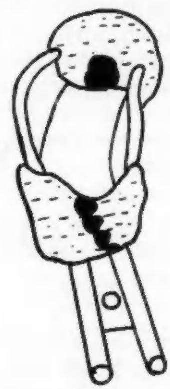


Fig. 3.

ture control indicators. There is no danger that the hydrocolloid will produce injury to the teeth at these temperatures.[9]

Following basic principles for inlay cavity preparations, the prepared field should be fitted with a properly prepared water-cooled tray. The tray is adjusted in the mouth by means of stops of modeling compound placed at the ends (Fig. 3). This minimizes movement during gelation and prevents the tray from being pushed against the occlusal surface of the teeth. A minimum thickness of ¼ inch of impression material must be present between the occlusal surfaces of the teeth and the tray. Most of the compound will roll over the border of the tray, which aids in the retention of the hydrocolloid.

Retracting the Gingival Tissue

At this stage in the procedure the field should be properly prepared for controlling the gingival tissue. The cavity margin must be exposed, since the hydrocolloid will not displace tissue or heavy fluids. This of course has been a major problem with this technique, but the retraction of the tissue should be by means of conservative

methods whereby the minimum amount of destruction or trauma of the tissue will occur. It may be necessary to use radical means when the tissue is edematous or inflamed; in such a case its removal is in the best interest of the patient and constitutes good dentistry.

Many methods are used for retracting tissue,[20] and each has advantages and limitations. All of the following methods actually are a compromise in one or more of the ideal requisites: (1) styptics, (2) chemical cautery, (3) surgery, (4) vasoconstrictors, and (5) mechanical.

After the toilet of the cavity preparations, the field is completely dried by the use of cotton rolls in the buccal folds of the upper arch or the buccal and lingual folds of the lower arch, and by gently blowing warm air into these areas. Retraction is accomplished by packing

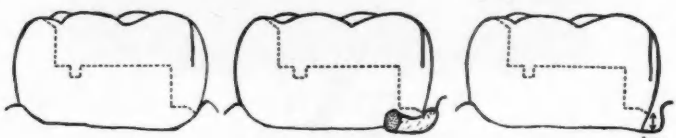


Fig. 4.

the crevice with short lengths (¼ to ½ inch) of cotton twine 1 mm. in diameter (Fig. 4). A large-gauge household twine must be used where the crevice is deep and greater displacement is needed. These cotton fibers are very effective if they have been impregnated with styptic crystals by immersing the twine in a 35 per cent solution of zinc chloride and then removing it and allowing it to dry. This twine which embodies the crystals then can be placed in a dispensing bottle, preferably one with a non-corrosive top. Similar results may be had by using string that has been treated with alum and racemic epinephrine 8 per cent. The short lengths of string are gently packed into the gingival crevice with the aid of a flat-bladed plastic instrument, such as the Tarno instrument (P.F. 1) or the Wagner. The string should extend around the buccal and lingual extension of the prepared cervical seat. Over this string a pack of dry cotton is placed to act as a compress and to absorb any seepage. The pieces of twine are left in place from 3 to 5 minutes and then removed just prior to the injection of the hydrocolloid. After the removal of the twine it is good procedure to have the patient rinse his mouth with warm water, in order to remove any excess chemical that might remain. Again the field must be thoroughly dried by isolation with cotton rolls and warm air. If any hemorrhage has occurred, it may be controlled by the use of a hemostatic. The utmost caution and discretion must be used when

radical and rather severe methods of retracting tissue have been employed. This will prevent any discomfort or injury to the patient.

Filling the Tray

In the next step the water-cooled impression tray, which has been previously adjusted in the mouth, is now filled with hydrocolloid from a tube taken from the storage bath. To aid in the elimination of folds and air bubbles in the hydrocolloid, extrude the material in the form of a large bubble and force it into the tray. Keep the open end of the tube or syringe in the material and allow the hydrocolloid to fill the tray without removing or moving the open end of the tube in the bubble until the tray is filled. Shape the mass with fingers that have been moistened in warm water, attach hoses to the tray and unit, and place the filled tray in a tempering bath for the proper time. This allows partial gelation and stiffening of the material. The stiffer and cooler hydrocolloid is more comfortable to the tissues, has less thermal contraction, is easier to handle, and will produce sharper cavity detail. Ideal tempering temperature is 115° F. for a minimum of 10 minutes. There are various tempering times, depending on how the office routine is organized. It is possible to produce sufficient gelation by using a lower temperature, 103° or 105° F., for a short period of time. It is obvious that tempering at low temperatures produces a more rapid drop in temperature. Thus, if a low temperature is used, care must be taken to time the tempering period carefully. The exact time-temperature combination to be employed depends on the particular office routine preferred, the exact consistency desired by the operator, and the composition of the hydrocolloid.

Taking the Impression

Again, it is important to make sure the field is dry. Remove the syringe directly from the storage bath and extrude part of the material, since there may be more water or air trapped in the lower part of the syringe. Inject the hydrocolloid to the side of the prepared quadrant of cavities first. Then start at the distal side of the posterior cavity and work to the most anterior part of the prepared quadrant (Fig. 5). The entire prepared tooth is covered with the material, and at all times the end of the needle should be held close to all tooth surfaces. The adjacent teeth on each side of the preparations should also be covered with the hydrocolloid. There is plenty of working time, but carry out the injection rather rapidly, since the hydrocolloid will cool fast when placed in the relatively cool teeth.

Fig. 5.

After completely filling all preparations, the assistant should remove the filled tray from the tempering bath and scrape off the top ⅛ inch layer. This contaminated layer will prevent a good union between the tray material and injected material. The prepared tray material is now carried to the mouth and carefully placed over the previously filled preparations. The tray is held firmly and chilled for at least 5 minutes. Adequate gelling time is necessary to allow the hydrocolloid to gain strength. With thermally controlled units the water circulating through the tray should be 70° F. and not lower than 55° F. If the water coming from the unit is too cold, the water should be turned off and on alternately until the hydrocolloid is chilled. Ice water or water below 55° F. is uncomfortable to the patient and causes strain in the hydrocolloid, creating greater chance of distortion.[1,5,12,16]

After chilling, the tray is removed with a quick motion in one direction parallel to the long axis of the tooth. Avoid weaving or teasing the tray from the mouth, either of which will cause fracture or distortion.[6,12] The impression is then checked for saliva, hemorrhage, and completeness of detail. If there is any saliva or blood, it should be gently washed away with cool water. The impression is then placed in a 2 per cent solution of potassium sulfate for 5 to 10 minutes. The use of this solution accelerates the set of the stone and thus produces a harder surface at the critical margins.[11,18]

The Working Die

There are a number of commercial stones that may be used with all of the hydrocolloids. Little difference exists in the physical properties

of the popular brands,[7] so selection will be based primarily upon color preference. A vivid yellow or white makes the critical margins clearly visible when waxing. Before pouring, blow out the excess solution of potassium sulfate, keeping just enough moisture to allow the stone to flow and set properly. Follow the recommended water-powder ratio of the manufacturer. One hundred grams with 24 to 25 cc. of water is usually adequate for pouring one working model and one opposing model. Mix for 1 minute with spatula or mechanical mixer or vacuum equipment; this minimizes air voids, increases strength, and provides a smooth model.[11,13] Place a small portion of stone on one side of the impression and under *mild* vibration allow the stone to flow slowly down one wall of the cavity, across its floor and up the opposite side. Completely fill the impression and allow to set for 30 minutes to 1 hour in a humidor or potassium sulfate solution before separation.[11] Prolonged storage of the stone in the hydrocolloid may result in a slight dissolution of the stone. Since the stone does not reach its maximal strength or hardness for some time, the model should be left in the humidor and no wax patterns should be fabricated for 24 hours.

There are innumerable techniques utilized for preparing and mounting the working cast, and each procedure has many possible variations.[2] Some of the methods used are as follows:

Plaster Matrix. Upon separation, the base of the cast is tapered and deep serrations are made on the bottom. The base of the cast is lubricated and then mounted in plaster, thus the plaster splint acts as a lock for the sectioned dies.

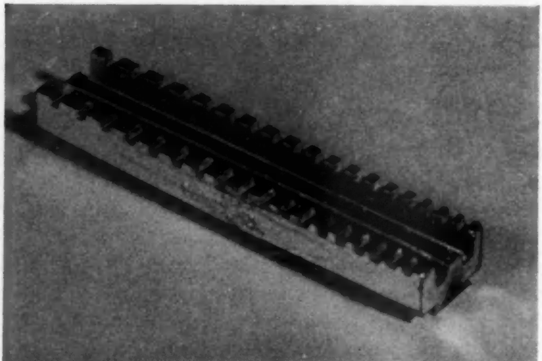
Paralleling Instrument. Accurate master models are made so that each individual die of the prepared teeth can be removed and returned to its exact position. The instrument centers dowel pins in the prepared teeth and parallels all pins, permitting removal of the dies without binding.

Typodon Method. Join the poured impression with Typodon pour. A sharp index can be obtained with this type of mounting.

Key Bar Method. Join the poured impression with the serrated surface of a Key Bar Guide[15] (Fig. 6). Since this method is a simple one and produces excellent results, a description of it follows.

Thin metal strips, 0.001 gauge, are carefully wedged in the impression between the individual cavity preparations (Fig. 7). Stability is obtained by contouring strips in such a fashion that they receive support from the buccal and lingual walls of the impression. Only the ends of the matrix metal engage the hydrocolloid, and the bottom of the metal is short of contacting the hydrocolloid at the cervical floor. Care must be exercised to prevent distortion during the insertion of

Fig. 6.



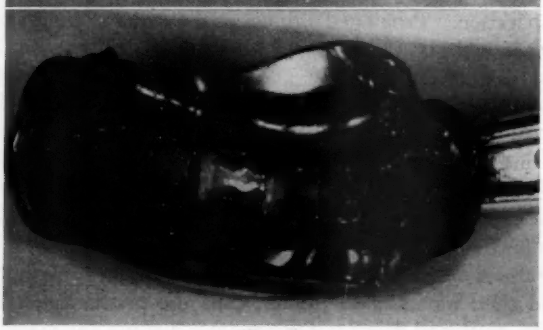


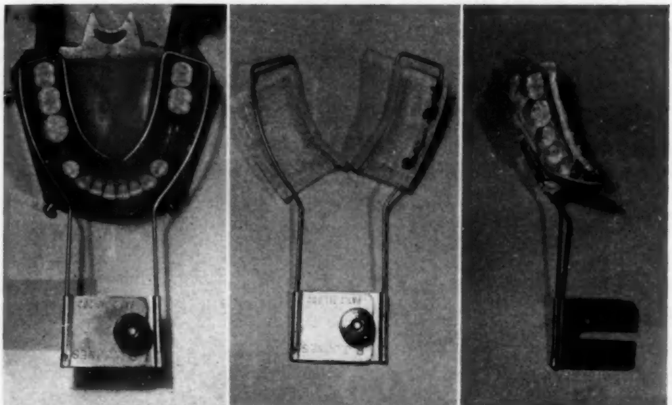
Fig. 7.

these strips. They must not be pushed too far cervically, and the metal strips must not be of a heavy gauge.[2] With the metal strips in place, the preparations are poured up to a level approximately 1 to 2 mm. short of the ends of the metal strips. The serrated area of the Key Bar is lubricated, partially poured and luted to the poured impression. Upon separation, the sectioning of the dies is facilitated by the metal strips.

After the working model and opposing model are properly shaped and trimmed, they are articulated by the use of a plaster splint or a bite that was taken with the Jones adjustable bite tray with the jaws in centric, and mounted on an articulator.[3] The Jones bite tray seems to be more accurate than the plaster splint, since the materials used (such as zinc oxide and eugenol pastes) offer no resistance when the patient closes in centric. The tray gives a firm buccal and lingual wall and a base which helps gain accuracy in placing the models together. It is a wire frame that may be used in a unilateral or bilateral position

(Fig. 8). This frame should be used with a gauze "bib" with a tube that is placed over the lingual extension of the frame. The loose end is placed under the buccal wing and held by sticky wax. A space must be left at the distal end between the bib and the frame, to permit the

Fig. 8.



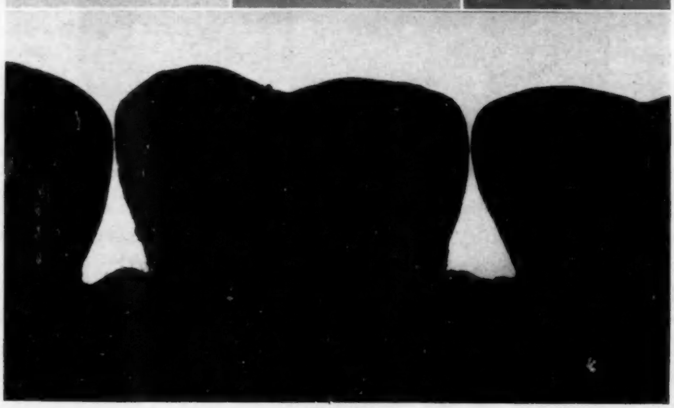


Fig. 9.

operator to see how to adjust and place the frame over the last tooth. This prevents the patient from closing on the frame. The paste is then mixed and placed on both sides of the bib. The frame is placed in the mouth, the patient closes in centric, and his lips hold the frame in position while the material is setting. After the bite is taken, release it from the buccal side and slide the tube and bite off the lingual wing. The tube itself lends all the support necessary in most cases.

After the case is mounted, the model containing the preparations is removed from the Key Bar. If metal strips were not used, the preparations are separated from each other by sawing up from the bottom of the model to within 3 mm. of the cervical area of the preparation. These parts are then pressed together, fracturing the remaining distance. If the metal strips are used, the preparations are separated by using a blunt instrument between the metal strip and the stone. With a Bard Parker knife under a magnifying glass, trim away the excess stone from the preparations at the clinical margins and also from the casts formed where the fracture was made. If this is not done the

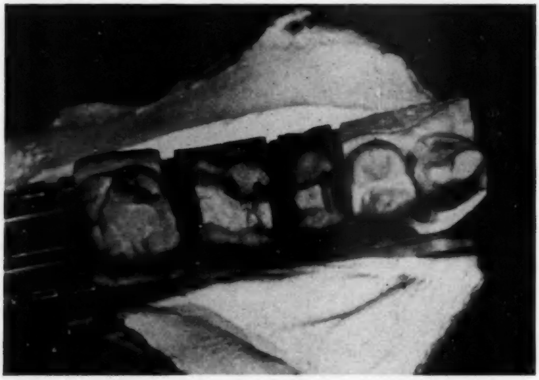


Fig. 10.

fractured parts will not go back into proper apposition and the contacts will be open (Fig. 9). Trimming this area is necessary, regardless of whether dowel pins, metal strips, or a solid cast is used.

Replace the separated sections on the Key Bar Guide and check the occlusion (Fig. 10). A commercial lubricant is then applied to the stone preparations for lubrication in waxing. It should leave a thin film on the die and be water soluble but it should not wash away easily.

The Wax Pattern

In the process of preparing the wax pattern the wax may be applied to the prepared die with heavy pressure with the fingers or by flowing the wax directly into the die. Marginal carving should be done with a blunt instrument because sharp carving instruments may cut the model. The finished wax pattern should be polished with cotton

tightly wound on cotton tweezers and warmed with water. The surface is polished with silk.

An effort should always be made to obtain the exact contour of the occlusal surface in preparing the wax pattern. The cusps, inclined planes and marginal ridges should correspond with those of the adjacent teeth. Particular attention should be given to the forms and locations of marginal ridges, since these have much to do with the excursions of food through the embrasures and the maintenance of the best natural cleanliness of proximal surfaces. The proximal contour should conform closely to the anatomic form of the tooth being inlayed. The reproduction of these details makes the inlay serve better in the protection of the septal tissue. After the marginal fit of the pattern is completed on the dies, the pattern is carefully removed, invested and cast.

The contact areas of the wax pattern should be a little heavy to allow for finishing of the casting and correct adjustment in the mouth. The inlay may be finished in the laboratory with fine sandpaper disks, burlew wheels, and soft-bristle Robinson brushes used with an abrasive polishing agent. This will remove fine scratches and polish at the same time. Care should be exercised to finish no closer to the margin than 1 mm. This marginal fit is so fine that it should be polished in the mouth. The margin has been cast to such a fine sharpness that it might easily be removed if it is polished in the laboratory and thus cause a submarginal fit.

In the development of this technique the operator's attention to detail in each step and the use of his skill and ingenuity will bring excellent results; carelessness will produce only failure and disappointment.

IRREVERSIBLE (ALGINATE) HYDROCOLLOIDS

It is difficult to compare objectively the merits of the reversible and the irreversible hydrocolloids for the fabrication of indirect restorations. The dentist should familiarize himself with both procedures in order to determine which technique will serve his particular practice the best and which will work most efficiently in his hands. Several points can be enumerated as sound arguments for either material.[10] The reversible hydrocolloids produce a better working surface on the die and a sharper detail of the cavity preparation. The selection of either material depends upon the type and amount of indirect work being done, auxiliary personnel and equipment. The alginates require little special equipment as compared to the reversible hydrocolloids. Since many of the variables associated with reversible hydrocolloids

are mechanically controlled, there is somewhat less chance for human error with their use. There is no doubt that there are more variations in individual batches of the alginate than in the better reversible hydrocolloids. This undesirable aspect has been and is being improved.

The proper armamentarium[8,14] for the alginate technique is as follows (Fig. 11): (1) proper proportions of powder and ice water; (2)

Fig. 11.

Fig. 12.

clean mixing bowl and spatula; (3) trays (perforated); (4) syringe (Hatch); (5) watch; (6) equalizing wax.

Some operators prefer a plastic bowl and spatula for mixing the alginate. A creamy consistency may be obtained with a stiff rubber bowl and spatula. The metal syringe (Hatch) is made specifically for this technique, is easily loaded and readily cleaned, and is much superior to the glass Luer syringes previously employed.

Preparing the Material

All alginates should be prepared routinely by agitating in order to mix the ingredients. Since they have different specific gravities, failure to blend the alginate ingredients may cause noticeable deviations in setting times. The manufacturer's directions should be followed closely in regard to the proper water-powder ratio.[17] With most alginates it is necessary to retard the setting time in order to provide the operator with the necessary additional working time and to allow the assistant ample time to flush and clean the syringe. This extension of time is usually accomplished by the use of ice water. However, one alginate* has sufficient working time to permit use of 70° F. water. When using alginates in warm weather, it is also desirable to chill the mixing bowl, spatula and syringe. To thin the mixture sufficiently for ejecting easily and evenly from the needle, the water-powder ratio may be increased. For example, the ratio of 56 cc. per package may be used rather than 50 cc. The use of ice water and a definite water-powder ratio standardizes the procedure and assures a constant setting time.

The proper amount of powder is added to the ice water, which has been placed in the chilled bowl. Mixing is performed vigorously, approximately 200 revolutions per minute, and should be completed at the end of 1 minute for all alginates. Insufficient mixing produces a grainy consistency, while prolonged mixing breaks up the formation of the lattice work of fibrils and lowers the strength of the material. When properly handled, the mix is creamy and free from bubbles and provides ample working time. The needle now is unscrewed from the syringe and the plunger is pushed all the way in. The needle is inserted into the alginate and the material is drawn up into the barrel by pulling the plunger out. To avoid air bubbles during the loading of the syringe, the end of the barrel should be kept amply covered with material and the plunger should be withdrawn slowly (Fig. 12). After the syringe is loaded, the needle is replaced and is ready for use. While the operator is injecting the material into the cavity preparation, an assistant loads the tray, using the remaining alginate. The sectional trays have been adjusted to the mouth previously by the use of equalizing wax, in the same procedure as for the reversible hydrocolloid technique. The wax is flame-softened and molded into each end of the tray to form a dam or stop. The tray is taken to the mouth and seated in such a manner that the prepared teeth are well centered within the tray. After the wax has hardened, the tray is removed. The

* Jeltrate, L. D. Caulk Co.

teeth adjacent to the preparations will have made indentations in the wax. These indentations act as a guide for placing the loaded tray in the correct position.

Taking the Impression

In taking the impression, extrude part of the material from the needle to the side of the preparation, since air may be trapped in the lower part of the syringe. The preparation should be filled first at the gingival portion in order to prevent bubble formation. It is advisable to work from the distal side toward the mesial side and to cover the entire tooth. The filled impression tray is then carried to place in the predetermined position and held under steady pressure so that no distortion results. At this time the syringe should be cleaned by the assistant, by pouring water into the barrel and forcing it out through the needle with the syringe plunger. When the alginate has gelled, it will lose its tackiness. It is necessary to hold the tray in the mouth for an additional 2 minutes to assure the formation of an adequate gel structure. If it is removed before the gelation is completed, the danger of rupture or distortion is increased. With a standardized technique it is possible to set an interval timer at the beginning of the mix and to remove the impression when the timer has signaled the expiration of the allotted time. The total time will vary with each alginate used, so the manufacturer's directions should be followed very carefully.

Since time is a critical factor, it is advantageous to use an interval timer throughout the alginate procedure. With most alginates, the material must be spatulated for 1 minute, the tray and syringe loaded and the prepared teeth filled within 2 minutes and the material allowed to gel for approximately 3 minutes before removal. If the impression is held in the mouth for 5 or more minutes instead of 2 minutes after gelation, distortion results,[13] probably owing to some loss of elasticity in the material. Therefore it is important that the mixing and removal time be controlled carefully.

As with the reversible hydrocolloids, the force used in the removal of the impression should be exerted with a quick snap and in the direction parallel with the long axis of the tooth. If it is removed with a slow rocking motion, rupture and distortion may result.

Most alginates do not require the use of an external fixing agent. When one is recommended, such an agent should be used.[13] Failure to use it results in a chalky or soft stone surface. If no fixer is recommended, the impression should be poured immediately. Some brands of alginates require 10 to 15 minutes fixing time, but more recently developed fixing agents have reduced the time to 2 minutes.

The Working Die

Because the final impression contains between 75 and 85 per cent water, it will tend to lose water (syneresis) if exposed to air and to pick up moisture if immersed in water (imbibition). This fluctuation in water content will cause contraction or expansion of the material and deformation of the impression.[12,19] The alginates show the greatest change when allowed to remain in air; likewise, storage in water will produce a large dimensional change. The best storage environment varies with the brand of material. Generally, the least change occurs in an atmosphere of 100 per cent relative humidity. Since there is no storage environment that will establish true equilibrium within the impression, it is best to pour it within 15 minutes after removal from the mouth.

The commercial hydrocals represent a weakness in the technique because they do not provide an indestructible working die. As with the reversible hydrocolloids, if care is not taken in pouring the impression, chalkiness, nodules or imperfections may require another impression. The excess water or fixing solution should be blown gently from the impression. The proper water-powder ratio of the stone must be observed when mixing, and the mix must be flowed into the impression with *mild* vibration. The poured model should be stored in a humidor and not separated for 1 hour. The mounting of the poured models and the fabrication of the working dies and wax patterns is the same as for the reversible hydrocolloids and should not be started before the end of 24 hours. Before it is waxed, the stone die should be treated with any of the various commercial separating media.

SUMMARY

Clinical success with the hydrocolloids depends on careful control of the many manipulative variables. With intelligent manipulation, the exactness of duplication of cavities allows multiple restorations to be coordinated one with the other on hydrocal models without the necessity of checking or fitting in the mouth. The main factors are:

1. Reversible hydrocolloid must be boiled for a minimum of 10 minutes and stored at a temperature of 145° or 155° F.

2. Various tempering procedures can be employed, but the degree of gelation and the working consistency will depend on batch composition, tempering temperature and time.

3. The cavity margin must be exposed, since neither agar nor alginate hydrocolloids will displace tissue or heavy fluids. Retraction of

tissue should be by means of conservative methods in order to minimize trauma.

4. The impression must be held in the patient's mouth for a minimum of 5 minutes and removed with a sharp thrust in one direction parallel to the long axis of the tooth.

5. For indirect techniques, most alginates require a higher water-powder ratio and the use of ice water for proper control of the setting time.

6. Either premature removal or a prolonged period in the mouth will influence the accuracy of alginate impressions.

7. Both agar and alginate impressions must be poured within 15 minutes.

8. The water-powder ratio, the amount of vibration during pouring and the length of time before removal of the die will influence the character of the stone surface.

9. The working dies show no discrepancies when the fractured parts are trimmed and the metal strips are not too thick or pushed too far into the impression.

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1121 West Michigan Street
Indianapolis, Indiana

Rubber Base Impression Techniques

L. Rush Bailey, D.D.S.

Synthetic rubber was not introduced to the dental profession in 1953 because of a lack of good impression materials; where indicated, the hydrocolloids (both alginate and agar agar), compound, waxes, plaster, Dietrichs, and zinc oxide-eugenol pastes are all excellent media for making impressions when properly manipulated. The development of synthetic rubber for dental use is the result of another attempt by the profession to improve upon the already excellent impression materials.

This article will attempt to give to the general practitioner an outline of successful procedures to follow in order to achieve success with rubber base impression materials in the majority of cases. In recent months considerable research has been done by Phillips,[6] Skinner, Ryge and others in regard to the synthetic rubbers. Their recommendations for handling this material will be included in this article.

SELECTION OF IMPRESSION MATERIALS

Some dentists and dealers and manufacturers like to think of certain products as being "all purpose" products, but there are very few of these so called "all purpose" products on the market today—certainly there are no "all purpose" impression materials. Surely it is reasonable to expect from an impression material only that which it is designed to do. For example, the prosthodontist has mastered more than one kind of impression material for his complete denture impression, knowing full well that various mouth conditions require various media for obtaining impressions of the edentulous ridges. The crown and bridge and inlay enthusiast has learned by experience that he must keep the field dry as well as cavity margins exposed if he is to be successful with his hydrocolloid impressions. The dentist must learn to choose the correct one and use it properly. One should not select an impression material which displaces soft tissue and expect to get an accurate impression of an edentulous ridge having easily displaceable soft tis-

sue, nor should one select the hydrocolloids when the control of saliva or marginal soft tissue seepage is an insurmountable problem.

It is true that the rubber base materials are the most versatile of the impression materials—they can be used in making impressions for complete dentures, partial dentures, crowns, bridges, and inlays. But they will not work successfully in every case.

HANDLING CHARACTERISTICS OF RUBBER BASE MATERIALS

Skinner[7] gives a very accurate account of the behavior of many of the synthetic rubber impression materials. Most of them fall in a fairly narrow range and handle quite similarly. In the main, it will usually be the one that works best in the operator's own hands that turns out to be his favorite impression material. Always follow the manufacturer's directions as to the proper proportions and spatulation times. Complete mixing of the material is essential. Control of temperature and humidity is necessary.[2] The fact that more and more dentists are going to air conditioned offices makes it possible to control the temperature and humidity, and thus materials such as cement, silicate and plastics, as well as impression materials, are uniform in behavior. This was borne out conclusively at the University of Alabama School of Dentistry. The first summer the rubber base impression materials were used in the clinic, air conditioning had not been installed and the results were quite erratic. The temperature was quite high and very often the impression material would set or cure as it was being loaded into the tray. As cooler weather came on this trouble ceased. Also the following summer no trouble was experienced along these lines because air conditioning had been installed in the clinic.

INDICATIONS AND TECHNIQUES FOR RUBBER BASE IMPRESSIONS

Rubber base impressions are indicated for single or multiple gold inlays, single or multiple crowns, fixed bridges, and partial or complete dentures.

It is not my intention to advocate the use of a rubber base impression technique for individual gold inlays. When a wax pattern can be carved satisfactorily in the mouth it is usually the method of choice. Those who prefer the indirect or indirect direct method can, in most cases, use the synthetic rubbers successfully.

Single Gold Inlays, Indirect Direct Method

Select an oversized copper alloyed tube, closed at one end. These alloys produce a rigid tube which will not be distorted after the im-

pression has been taken and thus ruin it. This impression tube can be contoured and shaped to fit the tooth similar to the way it is done in making a compound impression, with the exception that the tube is slightly larger. This allows for the elasticity of the rubber to come into play during removal over the height of contour and undercuts of the outer surface of the tooth. When satisfied as to fit of the tube, one must devise a way to make the rubber adhere to the tube. This is important because the tube acts as a tray, and an impression material must not come loose from the tray during removal. When this happens the impression is almost certain to be distorted. In the early days of the rubber impressions we found that the only method of obtaining

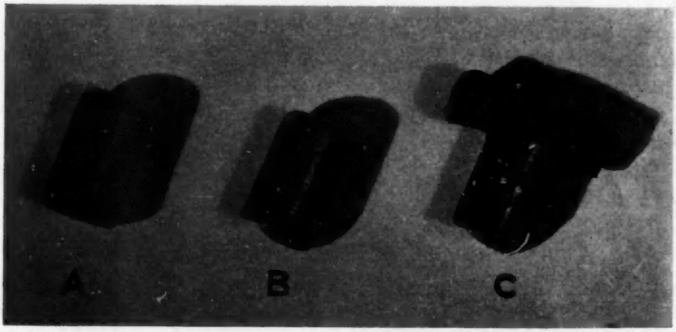


Fig. 1. Alloy impression tubes (*A*) before contouring, (*B*) after contouring the gingival, (*C*) with small holes drilled for retention and compound handle attached. Rubber adhesive is painted on the inside surface of the metal tube for added retention of the rubber impression material.

retention was to drill small holes in the tube to act as a mechanical retention. Later on some manufacturers included in their package a bottle of adhesive which was to eliminate the necessity of drilling the holes. I like either method, but I feel in this case that if a little is good a whole lot is better; therefore, I use both the holes and the adhesive, and it takes only a few seconds longer to be doubly safe. Place a compound handle, as shown in Figure 1.

Retracting the Gingival Tissue. The tube having been prepared, it is set to one side for later filling and use, and attention is given to drying the preparation (not dehydrating). Do this by isolating the area with cotton rolls or 1 by 1 inch rolled gauze squares, wiping the preparation with small cotton pellets and finishing with light blasts of warm air. Immediately tuck into the gingival crevice a string which has been impregnated with 8 per cent racemic epinephrine hydrochloride. This can be purchased from the dental supply houses in bottles with the string already impregnated with the vasoconstrictor. Cut the

string in lengths so that it is slightly longer than the circumference of the tooth, to allow for slight overlapping. If the string is dry after it is placed in the crevice (not on the crest of the gingival, as this is ineffective), it can be moistened (not flooded) with some of the solution of 8 per cent racemic epinephrine hydrochloride. The string is left in place about 4 minutes. This usually is long enough to produce a sufficient crevice for the impression material to enter and have adequate bulk to prevent distortion. This method of displacing marginal tissue has never, to my knowledge, caused sloughing of the tissues. Some people have questioned the advisability of using epinephrine in this concentration. Preliminary work has been done to determine the effect on blood pressure.[8] No demonstrable change was noted. This alone is not conclusive evidence that the drug could be used in large quantities over great areas of lacerated tissue, especially in cardiac patients, without some untoward effect. It was used in the Dental Clinic at the University of Alabama without any noticeable ill effect upon patients.

Making the Impression. Carefully remove the string from the crevice and if the crevice is sufficient and there is no hemorrhage or seepage of the gingival tissues, maintain this dryness and begin the mix of synthetic rubber impression material. Mix according to instructions as to proportions and time, fill the tube quickly, set aside, make a second mix, and carry sufficient impression material to the tooth preparation and apply. There are a number of ways to do this, using Jiffy tubes, small syringes which need to be cleaned after each use, small throwaway syringes and small brushes such as the ones used to apply plastic filling materials. The small cement spatula used to mix the material often can be used to advantage in the anterior of the mouth by carrying the rubber to the tooth and using it with a wiping motion to apply the material to the preparation. Any of these methods are satisfactory and usually the operator will find that one works better than another.

There are syringes designed especially for rubber base (Fig. 2). A small paper funnel is made and the mix of rubber is placed in the paper funnel and squeezed into the metal syringe. The plunger is then inserted and the syringe is ready for use. The plastic tips enter the cavity preparations quite easily and facilitate the placement of the rubber to the vital areas before the tray is carried to place. The syringe can be cleaned and used over and over again. When using the other syringe, the rubber impression material is mixed in the conventional manner, placed in a Dappen dish and drawn up into the plastic barrel as shown in Figure 3. Wipe off the excess rubber on the outside of the plastic barrel, reassemble the syringe and it is ready for use.

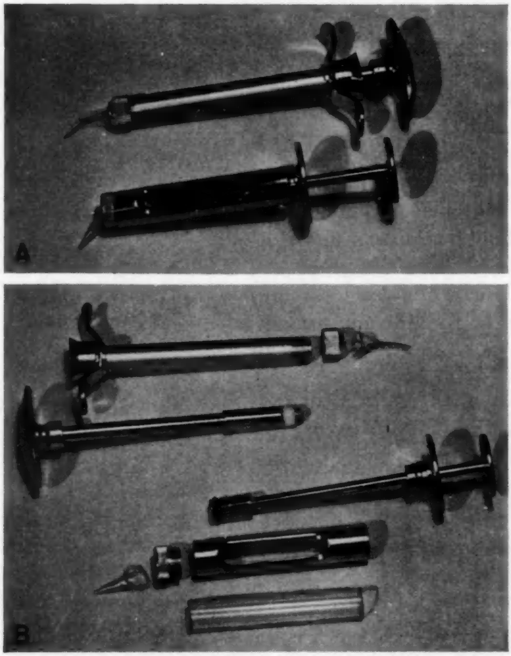
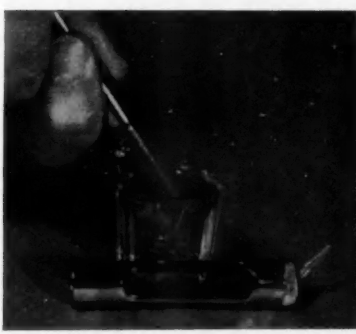


Fig. 2. *A*, Two syringes assembled ready for use. *B*, The syringes disassembled, showing the various parts.



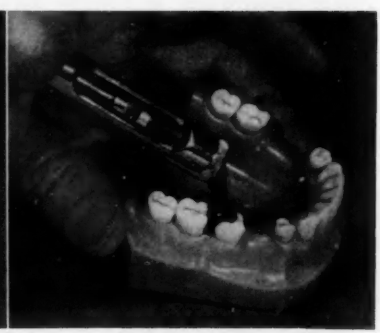


Fig. 3. Fig. 4.

Fig. 3. Loading one of the syringes by drawing the rubber impression material into the plastic barrel.

Fig. 4. This photograph shows the ease with which the rubber impression material can be placed in or on the cavity preparation prior to placing the previously filled impression tray.

Make every effort to eliminate the trapping of air by carefully applying the coating of rubber to the preparation. Don't expect the tray material to do this for you. If air is already trapped on the preparation, putting the tray to place will only reposition the trapped air and not eliminate it.

The preparation having been covered, the tube is carried to place with a gentle rotating motion, and curing or setting of the material is allowed to take place without the mass being disturbed. The time required is about 6 minutes.

On the lower arch the procedure is fairly simple. After the tube is put to place it is allowed to set in position without holding while the operator keeps the lips and tongue away and cautions the patient not to close so as to touch the tube. In the upper arch the tube must be held until set has taken place.

When sufficient time has elapsed, the tube is removed straight up from the lower arch and straight down for the upper. Inspect the impression; if it is clean and there are no bubbles present, dry and pour with a good stone and allow to set for one hour. Remove the stone die and apply separating media, then develop the wax pattern. Remove the wax pattern and carry it to the mouth to check for occlusion and proximal contact.

Multiple Gold Inlays, Indirect Direct Method

The same technique is used as for single inlays except that a tube tray must be made for each individual tooth preparation. Make individual impressions and stone dies on which to develop the wax patterns.

Single Gold Inlays, Indirect Method

Again some form of impression tray is necessary. There are several choices: prefabricated trays of metal or acrylic, hand-fashioned trays of quick curing acrylic or compound. It is my opinion that the tailor-made tray of quick curing acrylic is the best.[1] It can be quickly made on the study cast before the patient arrives. Other advantages of the acrylic tray are that it allows proper seating of the impression and maintains absolute stability while curing takes place; it allows for an even layer of impression material; it is not easily deformed during removal; and it has good stability after removal from the mouth during the pouring of the stone and while the stone is setting. These certainly are adequate reasons for the use of this tray.

When the tray has been checked in the mouth for proper fit, re-

move, dry, and drill a number of small holes for mechanical retention of the impression material, and also coat with a thin layer of adhesive for additional retention, then allow about 10 minutes for this to dry. See that the gingiva is retracted and the field dry. Mix the impression material, fill the tray, make a second mix and carry the necessary amount of the impression material to the preparation, and cover without trapping air (Fig. 4). Do this procedure quickly, and carry the tray to place. Stabilize for about 6 to 8 minutes, and remove with a quick thrust.

Producing the Stone Die and Working Cast. A proper mix of stone, which means a correct water-powder ratio and one free of air bubbles, is carefully vibrated into one area only. This area is the impression of

Fig. 5.

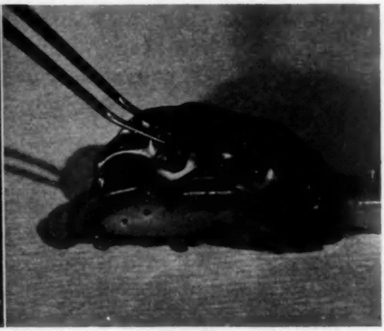


Fig. 6.

Fig. 5. Use of an instrument in placing and distributing the mix of stone over the surface of the rubber impression to prevent voids on the finished stone cast.
Fig. 6. Place the dowel pins as nearly parallel to each other as possible.

the prepared tooth. To facilitate pouring of this area a small amount of stone is carried to place with the small end of a No. 7 wax spatula, as shown in Figure 5. The end of the spatula is also used to aid the flow of the stone over the rubber surface by drawing it back and forth. This is necessary to prevent trapping small air bubbles on the surface, which would produce an inaccurate stone die. The Ney dowel pin is now placed in the center of the mound of stone (Fig. 6), and allowed to set for approximately 45 minutes. The stone is then moistened with water to facilitate removal and carefully lifted from the impression.

The rubber impression is now completely poured and allowed to set. This will be the working cast, as shown in Figure 7, which can be articulated to the opposing cast. The articulated working cast is used to secure the correct occlusal and proximal surfaces of the wax pat-

Fig. 7.

Fig. 8.

Fig. 7. The solid cast used for the working model in the construction of a fixed bridge. The two individual dies were made and removed from the impression before the solid cast was poured.

Fig. 8. Direction of saw cuts when removable dies are used.

tern. When this has been accomplished, the pattern can be removed and placed on the individual stone die and the margins of the wax pattern are carefully finished under a magnifying glass.

Multiple Gold Inlays, Indirect Method

For multiple gold inlays with the indirect method, the same outline can be followed as suggested for single gold inlays. The only difference is that an individual die is made for every tooth preparation. However, there are other ways to produce dies and working casts; in the following paragraphs are discussed three of these which I have used successfully and which have been advocated by other workers in this field of indirect work, namely, Sears, Thompson, Mann, and others.

Alternate Methods for Stone Dies and Working Casts. *The first alternate method* would consist of pouring the individual dies and placing the dowel pins. The placement of multiple dowels can be done by hand and sight, and they should be kept as nearly parallel as possible. The use of a mechanical paralleling instrument such as devised by Mann[5] would be helpful. After the stone has set, use a separating medium *only* on the dowel pins and individual stone dies. Pour up the balance of the impression, allow to set for 1 hour and remove. Using a small, thin saw, saw down each proximal area of each tooth preparation at an angle as shown in Figure 8 so that a light tap on each exposed dowel pin will release each die. It is obvious now why separating medium was placed only on the pins and dies to be removed; the other portions of the cast must remain in one piece. Trim the dies and replace them in their respective places on the cast. Place a small piece of soft carding or boxing wax over the exposed ends of the dowel pins,

and mount the cast on an articulator with an opposing cast. When set, flush out the soft wax with a stream of hot water and leave a small space for placing an instrument to push out each die needed and also to allow for proper reseating of the die.

As a second alternate method, many operators prefer to use a Typodon mounting. This is a plastic base which is keyed and equipped with a stainless tapered rod which locks the individual sawed dies back into the proper place.

For a third alternate method, a Key Bar may be used to mount the cast. It is a rectangular thin piece of polished metal, keyed so that the sawed sections of the working cast can be removed and replaced in the exact positions.

Any of these methods are acceptable and can be used with confidence. It has been clearly shown by Hohlt and Phillips[3] that the method used is not important, but that careful trimming of the die and replacing it to its proper place are essential.

Crowns

Crowns, like gold inlays, can be satisfactorily fabricated from a rubber impression if the operator has a cooperative patient, control of moisture, proper gingival retraction, and proper trays.

I have followed Kahn's technique[4] for jacket crowns, using the rubber impression instead of a hydrocolloid impression, and have found it very successful. In his technique, one impression takes the place of the copper tube compound impression, the wax cap which is used to seat the amalgam dies, and the plaster impression with wax cap in place.

Fixed Bridges

To complete fixed bridgework the steps used in fabricating multiple gold inlays and crowns may be followed. It should be pointed out here that, although satisfactory fixed bridges can be made from sectional or quadrant impressions, a better bridge can be made by using a complete impression and mounting the casts on an adjustable articulator, using proper mounting methods and jaw relationship records.

SUMMARY OF ESSENTIALS OF TECHNIQUE

There are a number of factors that are essential for success in making rubber base impressions. Keep the field clean and dry, but not dehydrated. Margins of all preparations must be free of gingival tissue. Fit the tray properly.[1] Use a rubber impression material you are fami-

liar with. Make a trial mix and use a watch with a second hand or a stop watch to check the mixing time and setting time. It is as difficult to estimate time as it is temperature; do not take a chance. Use a convenient and rapid method of getting the impression material to place. Stabilize the tray during cure or set of the rubber. The time varies for this procedure, but at the time of this writing it is about 6 to 8 minutes. Leaving it longer than the manufacturer recommends will not impair the impression. Remove it with a quick thrust. Wash the impression thoroughly, and dry and pour immediately.

Attempting to correct imperfections, such as small voids or bubbles on the impression surface, by adding new rubber to the already cured rubber is a dangerous practice. Remember, two objects cannot occupy the same space at the same time. It is not possible for the new rubber to flow out thin enough to prevent displacing the already cured rubber and thereby causing a distorted impression.

The rubber base impression material is a versatile one. Although it is not likely to replace the hydrocolloids, it is superior in some applications. It is truly elastic and has good dimensional stability. This attribute of dimensional stability should not be abused by leaving the impression unpoured for any length of time. The two mix technique[6] appears to be more accurate as well as necessary when using a syringe to inject in and around the prepared tooth. The quality of the surface of the stone dies and casts is excellent and in most cases is superior to those made from hydrocolloid impressions.[2]

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1121 West Michigan Street
Indianapolis, Indiana

Endodontics: Clinical Considerations Summarized

Harry J. Healey, D.D.S.*

Despite efforts to control it, dental caries remains at the present time as perhaps the most prevalent dental disease observed by the dentist in his everyday mouth examinations. Since the pulp of a tooth has its highest degree of protection and health when its crown is intact, both of those conditions are lessened proportionately by approaching caries. Eventual involvement of the pulp, as indicated by pain symptoms or detected through roentgenographic examination, demands careful attention and treatment by the dentist if the tooth is to be maintained as part of the patient's dentition. The other alternative, extraction, contributes to a crippling deviation from normal in the dentition from which there is no return.

The procedures and other attendant factors utilized in the treatment of pulpally involved teeth, whether the involvement be from caries, trauma or other causes, have recently been termed "endodontics." Endodontics can be defined as those surgical and therapeutic procedures employed in the protection of the pulp or in its removal from the pulp cavity when diseased or injured. The replacement by the term endodontics of the previously used synonymous terms, "root canal therapy," "treating or devitalizing of teeth," and others, characterizes an era in this field which has resulted from intense scientific investigation, development and progress. As a consequence, present-day endodontic therapy has been simplified, is decidedly effective and utilizes the clinical application of biologic principles and knowledge. No longer does confusion exist as to procedures followed, drugs used, results obtained, and effect on the patient's health.

SELECTION OF CASES

Regardless of the recent endodontic advancements, an initial determination of the amenability to treatment of a pulpally involved

From the Division of Endodontics, Indiana University School of Dentistry, Indianapolis.

* Professor of Operative Dentistry and Chairman, Division of Endodontics.

tooth must be made. Unwise selection of a tooth for treatment results in the rendering of treatments which lead irrevocably to the extraction of the tooth. Proper selection of cases followed by effective treatment procedures contributes immeasurably to the success of the ultimate result.

The importance of endodontic selection of cases has been pointed out and discussed in the literature.[1-3,6,8,10] The practitioner's own experience, in addition to the utilization of the knowledge and experience of others as expressed in the literature, makes it possible to determine criteria for selection of teeth for endodontic treatment. These criteria require an appraisal and a consideration of (1) systemic conditions, or the patient's general health, (2) local conditions in and about the tooth, (3) the essentiality or strategic importance of the particular tooth, (4) the endodontic ability of the individual dentist concerned, and (5) the availability of the patient for treatment.

THE NORMAL PULP

The dental pulp is a highly vascular, innervated connective tissue contained within the pulp cavity of a tooth. Microscopically, the pulp contains fibroblasts and reticular fibrils that form a meshlike arrangement within the ground substance. Resembling the fibroblasts and located near the pulpal blood vessels are undifferentiated mesenchymal cells. Polymorphonuclear leukocytes and lymphocytes are also found throughout the meshlike structure of the pulp. Histiocytes are present and participate with the other cellular elements in a defensive mechanism in times of pulpal injury.

Within the substance of the pulp is an intricate vascular system. Entering through the apical foramen as relatively large arteries, the vessels soon branch into numerous thin-walled tubes. These eventually end in the odontoblastic layer as a capillary network. The capillary network in turn gives rise to venules and subsequent small and then larger veins which emerge through the apical foramen.

Pulpal innervation is provided by the ingress through the apical foramen of myelinated nerves which are branches of the maxillary and mandibular divisions of the trigeminal nerve. A progressive branching into small nerves occurs. A terminal plexus of non-myelinated nerve fibrils forms at the outer limits of the pulp. Some of these terminal axons enter the dentinal tubuli. The peripheral limit of the pulp is formed by a layer of tall, cylindrical cells termed odontoblasts. These also send processes, Tomes' fibers, into the dentinal tubuli. The primary function of the pulp is the formation of the tooth. A peripheral and interstitial diminution of the pulp occurs when that function is

completed. In addition, the pulp continues to form patches of secondary dentin in response to invasion of the overlying dentin by attrition, abrasion, caries, and cavity preparation.

As mentioned previously, the pulp has its highest degree of protection when the crown of its tooth is sound and normal. Any deviation from the integrity of the crown increases the possibility of pulpal injury or disease. Clinically, the normal or vital pulp gives a positive pain response when submitted to any of the routinely used vitality tests. An exposed area of pulp is characterized by vascularity and sensation.

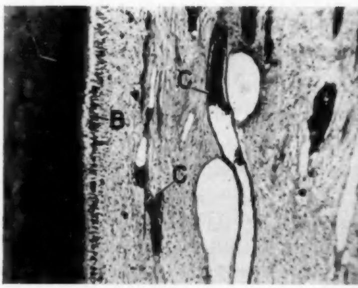

Fig. 1.

Fig. 2.

Fig. 1. High power photomicrograph of pulpal hyperemia. *A*, Dentin; *B*, odontoblasts; *C*, dilated pulpal capillaries engorged with blood. (Courtesy Dr. William G. Shafer.)

Fig 2. High power photomicrograph of chronic pulpitis. *A*, Dentin; *B*, diffuse infiltration of pulp by chronic inflammatory cells. (Courtesy Dr. William G. Shafer.)

PULPAL DISEASES

Hyperemia

Although pulpal hyperemia is not actually a disease of the pulp, it is the initial approach to definite deviation from normal. As in any hyperemia, it can be an active or arterial one in which there is an increase in afferent blood supply to the pulp, or a passive or venous kind in which there is a decrease in efferent blood flow. In advanced stages of hyperemia it is difficult if not impossible to determine when the condition ceases to be hyperemia and becomes pulpitis. Hyperemia (Fig. 1) can be caused by a variety of pulpal irritants, the degree or the amount of the irritation determining the exact effect upon the pulp. In some instances the irritation will act as a stimulant and will have a beneficial effect with a resulting deposition of secondary dentin. In others, hyperemia or, if the irritation is prolonged or increased in

severity, inflammation of the pulp or pulpitis will occur. Irritation of the pulp can result from injudicious use of instruments during restorative procedures, trauma from accident, disturbed occlusal relationship, instrumental separation of teeth, occlusal or cervical area wear, transmission of excessive thermal changes through metallic restorations, toxins and bacteria in approaching caries, certain restorative materials, and other sources.

The pain symptoms in pulpal hyperemia are transitory in nature and are induced by external stimulation as from cold air, cold water or food, or sweet or sour foodstuffs. The pain is uncomfortably sharp and disappears with the elimination of the inducing factor. Prevention of the causes of pulpal hyperemia is of utmost importance. However, once it has occurred, protection of the tooth from the inducing factors and the sedation of the pulp by the application of eugenol will return the pulp from its beginning deviation from normal.

Pulpitis

Prolonged application of irritants to the pulp will result in its inflammation, or pulpitis. Based on symptoms, pulpitis may be divided into chronic and acute types. The former (Fig. 2) is usually of longer duration and symptoms may be entirely absent or of a dull, annoying nature which are frequently tolerated by the patient until the condition terminates in pulpal necrosis. The acute type is decidedly more convincing as to its presence. Although its symptoms are much more violent and of a severe, sharp and stabbing nature, its course is not as long. This is due either to the natural more rapid arrival at its termination, which is also pulpal necrosis, or to the seeking of relief from the symptoms by the patient. An exposed inflamed pulp presents vascularity and sensation at the site of exposure. The acute type usually elicits pain response to a lesser amount of irritant than will a normal pulp when any of the various pulp tests are applied. The reverse is true in the chronic type.

Necrosis

The progressive nature of pulpal disease continues to necrosis. The pathologic vascular changes incident to pulpitis or to severe trauma are permanent, with pulpal necrosis the ultimate result. Pain symptoms incident to necrosis may be quite violent, intolerable, and of a comparatively short course. In other instances the "dying" process may be that of necrobiosis, with few or no symptoms and with termination requiring a long period of time. Necrosis appears in several varieties.

In coagulation necrosis the soluble portion of pulp tissue becomes a solid material. When this tissue conversion results in a cheesy appearance in the tissue, a form of coagulation necrosis designated as caseation necrosis exists. This cheese-like mass is composed mainly of proteins, fats and water which have undergone coagulation.

Gangrene occurs in the necrotic pulp as subsequent changes occur. This may be either moist or dry gangrene, caused respectively by liquefaction and desiccation. Further change in the necrotic mass caused by proteolytic or putrefactive organisms results in putrefaction or putrescence.

Clinically, the exposed necrotic pulp is characterized by lack of vascularity and sensation. Discoloration of the crown of the tooth in varying amounts may be present and no response can be obtained from pulp tests. A duller sound results from percussion of a tooth having a necrotic pulp than in the case of a tooth having a vital pulp. The tooth may be symptomless, or slightly tender, or severely tender with a feeling of elongation. In putrescence, a characteristic, foul odor is present in the necrotic mass. No response to vitality tests can be obtained in any of the kinds of necrosis.

Apical Periodontal Involvements

Although these are not diseases of the pulp itself, most of them are conditions which result from neglect of treatment of necrosis. In general, they are caused by the escape of irritating products of necrosis as well as bacteria and/or their toxins into the apical periodontal area.

Comprehensive considerations and discussions of these conditions have been made in the literature.[4,7,11,14] For simplicity and brevity the following descriptive listing of these conditions is presented:

1. *Acute apical periodontitis*—an acute inflammation of the apical periodontal membrane; may be accompanied by only slight tenderness in the tooth or by severe pain when pressure is applied to the tooth; either no roentgenographic deviation from normal or a thickening of the periodontal membrane.

2. *Acute apical periodontal abscess*—a localized collection of pus in the apical periodontal area; characterized by severe local pain and swelling as well as by symptoms of a general systemic reaction; no significant roentgenographic evidence.

3. *Chronic apical periodontal abscess*—a long-standing, diffuse, low-grade infection of the area; symptomless; roentgenographically, a diffuse area of rarefaction can be seen which is of diagnostic significance, together with a chronic draining sinus which may or may not be present on the mucosa.

4. *Subacute apical periodontal abscess*—a chronic abscess which suddenly flares up and manifests acute symptoms; roentgenographic evidence is the same as that of a chronic abscess.

5. *Apical periodontal granuloma* (Fig. 3)—a well defined growth of granulation tissue in the apical area; symptomless unless secondarily infected; in a roentgenogram it appears as a well demarcated area of rarefaction.

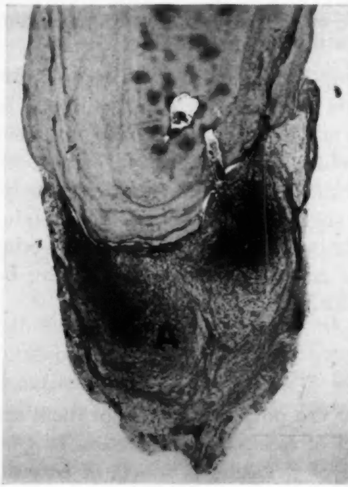

Fig. 3.

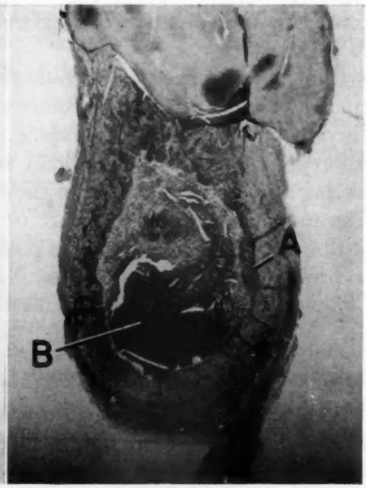

Fig. 4.

Fig. 3. Low power photomicrograph of granuloma. *A*, granulation tissue. (Courtesy Dr. William G. Shafer.)

Fig. 4. Low power photomicrograph of cyst. *A*, Epithelial cells; *B*, fluid content within lumen. (Courtesy Dr. William G. Shafer.)

6. *Apical periodontal cyst* (Fig. 4)—a slowly developing, epithelial lined sac in the apical area which contains a copious amount of a straw-colored watery fluid; symptomless unless size involves sensitive structures or if secondary infection occurs; in a roentgenographic examination it appears usually as a large area of rarefaction which is well limited by a light outline caused by evidence of the contiguous sclerotic bone.

Apical periodontal involvements present the usual clinical features outlined under *Necrosis,* above.

TREATMENT OBJECTIVES AND PROCEDURES

Diagnosis of the pulpal condition can be determined by the observation of responses to clinical tests, by the evaluation of the clinical

appearance of the exposed pulp, by the use of roentgenographic examinations, by the detection of color changes in the crown of the tooth, by the application of knowledge of symptomatology, and by the reaction to instrumentation when anesthesia is not being used. With the diagnosis ascertained, an understanding of the objective during each treatment appointment facilitates the efficient rendering of that treatment. In Tables 1 and 2 the objectives of each treatment, together

TABLE 1. *Pulpitis: Treatment Objectives and Procedures*

FIRST APPOINTMENT*	SECOND APPOINTMENT	THIRD APPOINTMENT
Objectives:	*Objective:*	*Objective:*
1. Pulpal sedation	1. Pulp extirpation	1. Obliteration of canal space
2. Reduction of pulpal bacterial activity		
Procedures:	*Procedures:*	*Procedures:*
1. Local anesthesia	1. Local anesthesia	1. Canal enlargement
2. Caries excavation	2. Gaining of direct access to canal	2. Filling of canal
3. Stimulation of flow of excess blood from pulp exposure	3. Removal of pulp	
4. Control and removal of blood	4. Control and removal of all traces of bleeding	
5. Eugenol treatment over exposure for 24–48 hours	5. Eugenol treatment in canal for at least 72 hours	

* In the absence of acute symptoms this first treatment can be eliminated if effective anesthesia has been obtained. The procedures to attain the second appointment objectives are begun immediately.

with the procedures utilized to attain those objectives, are outlined for pulpitis and necrosis.

It is not intended to imply that the use of the particular therapeutic remedies indicated in the treatment procedures is mandatory. The action of any drug in the treatment of the canal is secondary in importance to the thorough instrumental removal of the pulp material. For pulpal sedation and elimination of bacterial activity in pulpitis, among the drugs other than eugenol which can be used with adequate effectiveness are phenol compound and cresatin. The drugs used in the treatment of necrosis need not be applied in the sequence mentioned. Rotation of them in any order eliminates the possibility of development of microorganism tolerance to one drug, which might occur if it were used solely throughout the treatment procedures.

Note that bacteriologic testing of the canal prior to filling is not utilized in the pulpitis procedures. Actually, it is the author's policy

to make such culture tests if the slightest doubt exists as to the thoroughness of the previous treatment procedures or as to the existence of the required favorable clinical conditions of (1) no tenderness in the tooth, (2) absence of foul odor in the canal, and (3) lack of excessive exudate in the canal. Experience has shown that pulpitis

TABLE 2. *Necrosis: Treatment Objectives and Procedures*

FIRST APPOINTMENT	SECOND APPOINTMENT	THIRD APPOINTMENT	FOURTH APPOINTMENT*
Objective:	*Objective:*	*Objectives:*	*Objective:*
1. Initial reduction of canal sepsis	1. Complete reduction of canal sepsis	1. Verification of canal asepsis	1. Obliteration of canal space
		2. Enlargement of canal	
Procedures:	*Procedures:*	*Procedures:*	*Procedure:*
1. Complete removal of entrance to canal	1. Thorough cleansing of canal	1. Bacteriologic culture test	1. Filling of canal
2. Elimination of pulp chamber debris	2. Irrigation of canal with 4% chloramine solution	2. Completion of instrumental preparation of canal	
3. Cresol treatment placed at entrance of canal for 24–48 hours	3. B. creosote treatment placed in canal for 24–48 hours	3. Fitting of master gutta percha point	
		4. Irrigation of canal	
		5. Camphorated para-monochlorphenol treatment placed in canal for at least 72 hours	

* If culture taken at previous appointment is positive, (1) take new culture to test the effectiveness of the treatment procedures which were followed at third appointment *after* taking initial culture. (2) Assuming that canal still contains contaminated debris, thoroughly repeat the remainder of the treatment procedures of third appointment.

cases thoroughly treated and carefully analyzed for the presence of favorable clinical signs are routinely accompanied by negative culture tests. The elimination of the culture-taking appointment is a beneficial economic and convenience factor for both the dentist and the patient and does not endanger the outcome of the result. The author, however, checks the aseptic nature of his procedures by culturing his pulpitis cases at definite periodic intervals.

Apical Periodontal Involvements. The objectives in the treatment of these conditions can be generalized as follows: (1) Removal of the cause, i.e., pulpal degradation products and/or associated bacteria, and (2) obliteration of the canal space. The procedures utilized to attain those objectives are (1) drainage via the root canal and the parenteral use of antibiotics in acute conditions; (2) same procedures as in the treatment of necrosis; (3) surgical intervention if needed; and (4) postoperative roentgenographic checkup at 3 to 6 month intervals until healing is complete. The indications and contraindications for surgical intervention have been previously discussed in the literature by the author.[8]

Conservative endodontic treatment, or that not utilizing subsequent surgical intervention, is highly recommended when indicated. In such

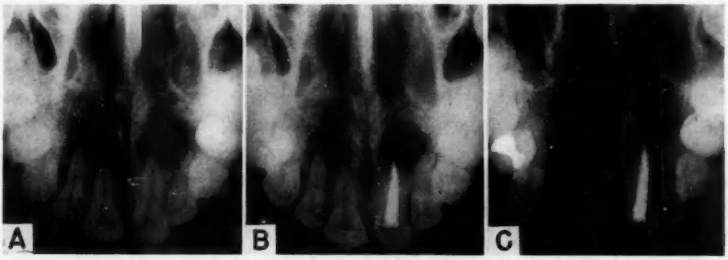

Fig. 5. Apical periodontal healing following conservative treatment. *A*, Diagnostic roentgenogram; *B*, canal filled; *C*, subsequent healing.

instances surgery is entirely unnecessary, since the causes of the apical periodontal lesion, i.e., the bacteria or their products and/or the irritating products of pulpal degradation, are removed and the canal is obliterated by the endodontic therapy. Osteogenesis then occurs with healing of the lesion the result. Figure 5 illustrates roentgenographically the healing of a large area of apical periodontal involvement following conservative treatment of an upper central incisor. This patient was a female, age 25 years; owing to the size of the original lesion, the healing shown required 28 months.

Canal Débridement and Enlargement

One of the most important phases of endodontic therapy is the adequate preparation of the canal with suitable and specially designed instruments. Such instruments include (1) barbed broaches, the working portion of which is characterized by numerous barbs which are used for the removal of gross amounts of loose pulpal tissue or degradation debris from the canal; (2) files, which are used for removing

debris adhering to the canal walls and for enlarging the canal through the utilization of their rasp-like cutting areas; and (3) reamers, which have a function similar to that of files but which is accomplished by their four spiralling blades.

Pulp Removal. The extirpation or removal of the pulp in the treatment of pulpitis requires the use of as large a barbed broach as will pass to the apical end of the root canal. In order not to lacerate the pulp severely, which would complicate its complete removal, the instrument is not passed through the center of the mass of pulpal tissue but, rather, closely alongside a canal wall surface until it reaches the end of the canal. This extent is determined by the use of the operator's knowledge of the approximate length of the particular tooth being treated, the roentgenogram of the tooth, and the meeting with resistance by the broach from the apical constriction of the canal. The broach is then moved medially into the center of the mass of pulpal tissue and rotated slowly several times. This action entangles the pulp tissue in the barbs of the broach, and when the instrument is removed from the canal, the intact and complete pulp accompanies it. The rather profuse bleeding which usually ensues is controlled, and the accumulated blood is grossly removed by a series of sterile, blunt-end absorbent points. This is followed by irrigation of the canal with sterile distilled water for the final removal of blood, and then by the re-drying of the canal.

Removal of Necrotic Pulpal Debris. Although the combined results of investigations by Seltzer and Bender[13] and Ostrander and Crowley[12] have shown that approximately 36 to 40 per cent of necrotic pulps are free of bacteria, it is not consistent with good judgment to assume that a particular case at hand is among the group of bacteria-free necrotic pulps. At the time of the initial treatment of necrosis when the entrance to the root canal has been completely removed, it is not possible to determine reliably the presence or absence of bacteria in the necrotic pulp. Hence, it must be assumed that bacteria *are* present. The initial germicidal drug treatment is sealed in to overcome or inhibit the growth of the probable bacteria to some extent at least.

During the second treatment, therefore, the canal can be completely débrided with less danger of forcing infected material into the apical periodontal area and thereby inoculating it and causing an acute infection. The débridement is accomplished first of all by removing and discarding the loose or gross debris within the canal through the use of a barbed broach manipulated progressively from the entrance of the canal to its apical end. With this accomplished, the canal is irrigated with 4 per cent chloramine solution and is left filled with the irrigating solution. It is necessary now to do the second portion of the

canal cleansing procedure, which is the removal of debris adhering to the canal walls. To do this, suitable broaches and files are used to cleanse all canal wall surfaces. Visualization of the diameter and length of the canal assists in achieving thoroughness. Frequent irrigation of the canal removes debris loosened from the walls by the instrumentation, exerts a slight dissolving action on the remaining debris, and provides an antiseptic washing of the canal.

Enlargement of the Canal. To enlarge the root canal properly for filling requires skill, digital dexterity and patience. The enlarging procedures remove affected dentin from the walls of the canal and shape the canal for the accommodation and proper fitting of the master point which will be used in the filling of the canal. With the inciso-(or occluso-)apical length of the tooth determined by a roentgenographic verification of a file properly placed in the canal as seen in Figure 8*B*, the possibility of trauma to the apical periodontal tissues incident to the enlarging procedures can be eliminated. The canal is enlarged through the use of files Nos. 1 through 6 and/or reamers which can be limited in their apical extent to the predetermined measurement by (1) the placing of a small circular piece of rubber dam on the shank of the file at the incisal termination of the measurement, or (2) the attachment of specially designed instrument stops, or (3) the use of instruments capable of being adjusted to the determined length. The 1 to 6 series of files has a gradual and sequential increase in size, the previous file not being discarded until the canal is enlarged sufficiently to permit the next larger file to pass to the end of the canal. Filings can be removed by broaching and irrigating from time to time.

The action of germicidal agents is lessened in the presence of organic material. Thus it is imperative that adequate time and attention be given to the débridement and preparation of the canal during endodontic therapy. The mechanical lavage and the antiseptic action of the irrigating solution assist the thorough use of broaches and files in properly preparing the canal. This, in turn, permits a more effective action of the germicidal agent which is to be sealed into the canal.

Irrigation of the Canal

It has been pointed out that irrigation of the root canal during its instrumental preparation assists in the thoroughness of the procedure. Four per cent chloramine is one of several effective irrigating solutions. It can be prepared by dissolving four 4.6 grain chloramine tablets and 3.6 grains of sodium chloride in 1 ounce of sterile distilled water. Varying amounts can be prepared by a corresponding varying of the ingredients. Larger amounts should be kept in a dark-colored

bottle. The instrumentarium required for irrigation (Fig. 6) consists of a blunt needle, glass barrel syringe (B-D, No. 02Y Special, recommended) and a supply of 2 by 2 inch absorbent squares or other suitable absorbent material.

With the solution drawn into the barrel of the syringe, the blunt needle is placed about halfway to the apical end of the canal without completely blocking the canal. A folded absorbent square is placed at the external opening of the crown of the tooth. The solution is carefully discharged into the canal with only sufficient pressure to cause it to flow to the end of the canal and then reverse its course through

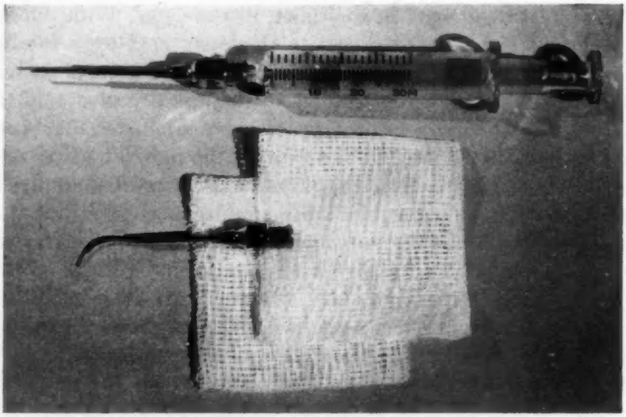

Fig. 6. Glass barrel syringe, two blunt needles and absorbent squares—for canal irrigation.

the canal and out the crown aperture, where it is accumulated in the previously placed absorbent square. The effectiveness of the lavaging action is indicated by the deposition of debris on the absorbent material. The eventual discontinuance of such deposition after further instrumentation and irrigation assists in the determination of the thoroughness of removal of the canal debris. Excessive syringe pressure upon the chloramine solution during irrigation should be avoided. A consequence to such excessive pressure is the forcing of possibly infected debris and the highly irritating solution into the apical periodontal space.

Bacteriologic Culture Testing

The canal is examined for the absence of bacteria through carefully directed culture testing under aseptic conditions. Such testing is done

only when the previously described favorable clinical signs are observable. With the previous treatment removed, the canal is swabbed with a series of sterile, blunt-end absorbent points to remove any remaining traces of the previous treatment drug. These points are discarded. Using sterile cotton pliers, a sterile, *tapered-end* absorbent point is carried well up into the apical region of the canal. It is desirable that this procedure result in the extension of the tapered end of the absorbent point into the apical periodontal area for the purposes of absorbing tissue exudate from that area. The absorbent point is

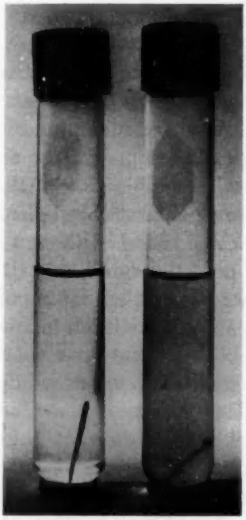

Fig. 7. Negative culture, left; positive culture, right.

brought into contact with the canal wall surface in its entirety. It is removed from the canal and deposited in a tube of thioglycollate or other suitable culture medium. After the tube is labeled with the patient's name and the date, it is placed in a body-temperature incubator for at least 72 hours. To determine the adequacy of the aseptic technique in the taking of the culture test, a second sterile point is carried with the same cotton pliers through the path of the original one with the exception of its insertion into the canal. It is similarly labeled (with a further designation by the word "control") and is incubated in a like manner.

At the end of the incubation period, the maintenance of the original clearness of the medium (Fig. 7, left) indicates a negative culture. In the case of the test culture this verifies the sterility of the canal. In the

control culture this assures the aseptic nature of the test-taking technique. The development during the incubation period of a clouding, turbidity, or muddying in the medium (Fig. 7, right) signifies a positive culture or the growth of bacteria originating, in the test culture, from the canal, and in the control culture, from instrumental or other contamination during the testing procedure. A positive test culture with a negative control culture makes further treatment of the canal necessary. If any doubt as to the reliability of a negative culture test exists, another one should be taken.

Filling of the Canal

The attainment of the treatment objectives by the procedures previously discussed results in the readiness of the canal for the obliteration of its space. The determination of this readiness is made by the obtaining of negative culture tests and by the presence of favorable clinical signs. The combination of these factors indicates an aseptic canal condition and a favorable apical periodontal condition for the tolerance of the canal filling. Although a marked improvement then exists in the tooth over the condition at the time of its selection for treatment, the success gained thus far is only a part of the over-all procedure required to maintain the tooth in a state of health and function. It is necessary to obliterate the canal space completely with non-irritating and hermetic sealing materials. Failure to do so will result in the accumulation and stagnation of tissue fluids in the unfilled canal or in any unfilled apical portion thereof. These stagnated fluids provide an excellent nidus for microbial growth with inevitable acute or chronic apical periodontal involvement. Adequate attention, therefore, should be given to the canal-filling portion of endodontic therapy.

Materials. At the present time, owing to the ease of their manipulation and the excellence of the result that can be obtained through their proper use, gutta-percha with an antiseptic and sedative cementing or sealer substance undoubtedly enjoys the most popularity and usage. It has been the author's experience that Kerr's Antiseptic Pulp Canal Sealer, the original formula for which was suggested by Rickert,[5] supplements the gutta-percha quite effectively. The resulting canal filling is non-irritating and well tolerated by the soft tissues, has permanence of form, exerts sedative and antiseptic actions, is radiopaque (and thus readily observable by roentgenographic examination), and can be easily removed if need be.

Methods. Several procedures may be followed in filling the canal. The one of choice in a particular case is determined after a consideration of the size, shape and general anatomy of the root canal.

The lateral condensation method is effective in the naturally larger canals and in canals which have been enlarged to the extent that their spaces require for their obliteration or obturation a main or master gutta-percha point supplemented by smaller auxillary gutta-percha points and the sealer substance. The procedures require the roentgenographic verification of a properly fitted master gutta-percha point. To fit properly it should be as large a one as will pass completely to the end of the canal and with the adjusted cross section of its apical portion of such diameter that it will block the foramen. Such blocking will prevent its protrusion into the apical periodontal space during the subsequent canal filling procedures.

The canal is given a final antiseptic and dehydrating lavage with 95 per cent alcohol and is thoroughly dried with blunted, sterile absorbent points. The master gutta-percha point is seated to its correct location in the root canal, the walls of which have been coated with a thin but thorough coating of the antiseptic sealer substance. Using a contra-angle root canal plugger, the master point is condensed laterally against any canal wall surface to which it will go most readily. This eliminates the space on the one side and decidedly increases the space on the other sides of the master point. The increased space is then filled in by a series of previously prepared, smaller, auxiliary gutta-percha points, each one of which, in turn, is similarly condensed laterally.

Careful execution of the lateral condensation method will completely obliterate the root canal space. This is verified by an evenly white-colored root canal filling as seen in a roentgenogram. A deviation from that desired appearance as shown by gray voids would be due to inadequate condensation with a resulting improperly filled canal.

The sectional method is preferred by some for the filling of large canals as well as smaller ones. It is particularly indicated for the filling of the canal of a tooth which, because of extensive loss of coronal substance, will require a metallic post in the root canal as retention for the restoration of the crown subsequent to endodontic therapy. In this method the apical 3 to 4 mm. section of a previously fitted master gutta-percha point is cemented into its correct apical location in the canal, using the antiseptic cementing substance. The remainder of the canal space is then obliterated by condensing into it a series of sections of gutta-percha which have been softened by slight warming. The resulting secureness of the important apical portion of the canal filling guards against its dislodgement when enough of the filling is removed for the accommodation of the retentive post.

The sectional method also is effective in the filling of the canals of

teeth wherein the apices of the roots are not completely formed and the canals are extremely wide. In such a case, a large master gutta-percha point inserted butt end first into the canal is properly adjusted and fitted. The apical segment is sealed in its correct position and the remainder of the canal is left unfilled until the return of the patient for the next appointment. At that time, the efficacy of the sealing of

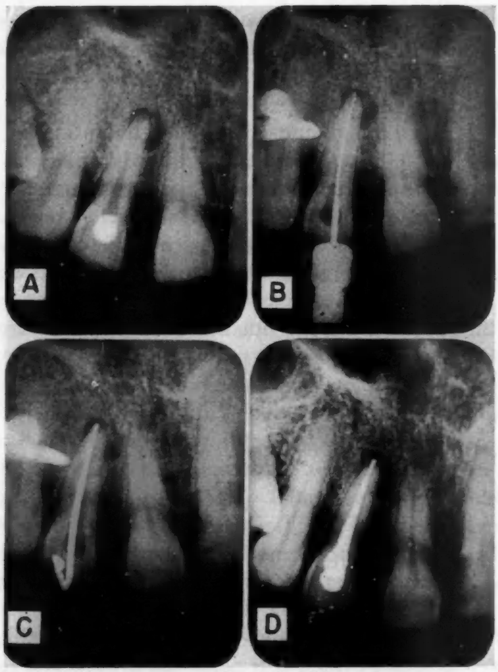

Fig. 8. Lateral condensation procedures for filling the canal using a "master" silver point. *A*, Diagnostic roentgenogram; *B*, measurement file registering length of the canal; *C*, master silver point fitted; *D*, canal filled.

the apical foramen by the previously placed gutta-percha segment is determined by the lack of intracanal periapical fluid seepage. If conditions are favorable, the remainder of the canal is then filled by completion of the sectional method procedures.

The single point method, which is advocated and used by some, is of lesser value in the author's opinion. This method is used in those canals which, because of their small size, can be almost completely obliterated by the use of one gutta-percha point. The sealing of a

properly fitted point into the canal with the antiseptic and sedative cementing substance results in the obliteration of the entire canal space. When this method is used, assurance that the canal walls have been cleansed thoroughly and are comprised of unaffected dentin is as essential as in the other two methods. Usually the accomplishment of those conditions by proper enlarging of the canal will result in a canal size which is amenable to the more effective lateral condensation method.

Silver Point Technique. Jasper[9] has developed and refined the use of master points of silver in filling certain canals having unique anatomic characteristics. The curved, narrow, or tortuous canals often occurring in the lower anterior teeth and the upper bicuspids, the buccal canals of upper molars, and the mesial canals of lower molars are more amenable to the fitting of the slightly stiffer silver point than of the softer gutta-percha point. In many other cases where the single point or lateral condensation method is to be employed, a master point of either silver or gutta-percha can be used optionally with equally effective results. The use of silver points, however, is contraindicated in the canals of teeth that have such extensive loss of coronal tooth substance as to necessitate the use of a metallic post in the root canal as retention for the ultimate restoration of the crown of the tooth. This is because of the difficulty or even impossibility of removing a portion of the canal filling for the accommodation of the retentive post without dislodging the important apical portion of the filling. Figure 8 presents roentgenograms of the procedures followed in the lateral condensation method for filling a canal using a master silver point.

SUMMARY

Present-day endodontics is decidedly effective and is an excellent example of the application in dentistry of information gained from allied biologic fields. Applied microbiology, pharmacology, histopathology, biochemistry and others of the biologic sciences enable endodontics to be practiced on a rational basis rather than in the empirical manner which characterized its earlier history. The concurrent clinical development of improved methods, materials, instruments and concepts has provided simplified and effective treatment procedures. No longer does doubt and confusion exist as to objectives of endodontic treatment and the procedures to be followed to attain those objectives. As a consequence to the foregoing, endodontics can now be practiced with complete confidence as to the final result.

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1121 West Michigan Street
Indianapolis, Indiana

SYMPOSIUM ON DIFFERENTIAL DIAGNOSIS OF PROSTHODONTIC NEEDS

Foreword

The slow process of impairment and loss of physiology of a part or all of the masticatory structures is a major concern of the prosthodontist. It is a concern because the responsibility for restoration places within this special field of dentistry a broad definition and requirements of clinical knowledge. To restore oral physiology to any degree of normalcy, it is necessary that the prosthodontist have extensive experience and training in all the sciences of dentistry to make a proper diagnosis and plan adequate treatment.

It is unfortunate that there exists in some areas today a segmentation of the field of prosthodontics. To divide the subject into separate subspecialties of complete, fixed partial and removable partial prosthesis is unrealistic and a denial of basic knowledge. To properly make an adequate diagnosis and formulate a plan of treatment that can visualize the end result requires a full knowledge of prosthodontics. It has been said that the prosthodontist has to have a broad knowledge of all the arts and sciences of dentistry. This most certainly is so, for diagnosis must call upon a broad knowledge in the basic sciences linked to the clinical sciences allied to the prosthetic field.

If the problem were one which required only the extraction of the remaining teeth and the placing of artificial substitutes, the solution would be simple, presupposing, of course, that there was no alteration in normal anatomy and physiology of the integument. The prosthodontist, however, is presented with a totally different set of problems and complexities.

When one or more teeth are lost at an early age, there is collapse of the entire dentition to varying degrees. Paralleling these changes is the well known syndrome of lost or impaired function with resulting dysfunction and the creation of traumatic influences which affect the periodontal structures; the incidence of caries is also greatly increased, and the sum of these processes results in the clinical picture so familiar to all dentists.

Diagnosis should be approached on the basis of restoration of func-

tion. Every effort must be made, when approaching diagnosis, to preserve the remaining structures if at all possible. The complete denture should be the last consideration, arrived at only when all other avenues have been closed.

A complete history and collection of data at the time of diagnosis, relating to the general health of the patient, is necessary for the success of prosthetic restoration. Prostheses placed for patients who are not well physically or mentally seldom prove entirely satisfactory and frequently fail. Differential oral diagnosis is only possible when all of the data have been correlated and supplemented with adequate roentgenograms and casts mounted by scientific transfer.

Raymond J. Nagle, D.M.D.
Dean, New York University
College of Dentistry

Diagnosis of the Edentulous Mouth and the Probable Prognosis of Its Rehabilitation

JOSEPH S. LANDA, D.D.S.*

There are few disciplines in which art and science are as intimately interwoven as in the specialty of dentistry. This is most vividly reflected in differential diagnosis of oral conditions and their management in complete denture prosthesis.

The edentulous mouth is studied in the clinic by methods of simple inspection—visually, radiographically, by digital examination, by special biomechanical procedures, by eliciting direct information from the patient and by gathering important data of the patient's life story from friends and relatives.

Since the edentulous oral cavity is most often seen after the age of fifty, its diagnostic problems may also involve those of geriatrics. Because the effect of aging upon different organs and systems of organs varies greatly in different individuals, it is important to make a careful evaluation of any degenerative diseases that may be manifest in the edentulous patient. Even in the absence of any specific disorders, the aged patient cannot be free of involutionary changes in his tissues and organs. The involutionary changes, in turn, reduce the *functional reserve* of the tissues and organs affected. While this condition can hardly be measured by any yardstick, it is present in most instances though in varying degrees.

To clarify this concept let us cite an example from the most important organ in the human body, the heart. The heart muscle is supposed to have a functional reserve 20 times in excess of the demand made upon it by daily average activity. Thus, the young prize fighter's heart may be subjected to a strain almost 20 times as great in the ring as when he takes a leisurely morning walk. The same holds true for the young boy on the race track. But when athletes reach the age of forty, the fundamental reserve of their heart muscle has been so

* Professor of Denture Prosthesis (Postgraduate), New York University College of Dentistry.

reduced that they have to retire from their sport. The entire cardiovascular system, the respiratory system and the kidneys are similarly affected but, of course, in different degrees. The edentulous oral cavity as an involutionary masticatory mechanism is no exception in the human body.

This concept is of genuine practical significance in differential diagnosis of the various conditions of the edentulous oral cavity. The latter performs a large variety of different functions—mastication, deglutition, breathing, phonation and speech production. In view of its multiple role the masticatory mechanism consists of a chain of physiologic links. The impaired function of one of them requires compensatory adjustment of the other links. This intimate interdependence of function among the structures and organs of the edentulous mouth demands keen insight from the diagnostician for proper placement and distribution of stress among the various links. A miscalculation in stress placement, burdening a vulnerable link, may cause the entire structure to collapse. In this case a certain organ or tissue, represented by the vulnerable link, lacked adequate functional reserve to withstand the stress. In other instances, the depletion in the functional reserve of the aging edentulous oral structures is not pronounced and adjustment is uneventful. Again, the depletion of the functional reserve of the edentulous mouth may occur without any clear-cut manifestation of structural change or clinically demonstrable lesions. On the other hand, situations are encountered in which the organs and tissues of the senescent masticatory mechanism have retained a fair functional reserve potential but the patient's emotional status is warped. In the present state of our knowledge we cannot assess these situations with any degree of exactness but they are nonetheless a clinical reality and the diagnostician must bear them in mind at all times. *By and large, the aged person adjusts himself gradually through the years to the handicaps of senescence by decreasing his activities to a level compatible with his own appreciation of the functional reserve available in him.*

The dentist should not lose sight of this basic truth when confronted with difficult decisions in oral rehabilitation, such as whether partial or complete dentures should be utilized. Correctly diagnosed and properly constructed partial dentures are always to be preferred to complete dentures. Even if the remaining natural teeth cannot be expected to render optimal service, an average serviceable partial denture restoration is still preferable to a complete denture. There are many reasons for taking this position. The main point is that *the removable partial denture helps the aged patient to adjust himself gradually to the handicaps of senescence.*

The differential diagnosis for correct timing of the transition from natural to artificial dentures is also greatly dependent upon the psychologic state of the patient. Some patients may take the loss of their natural teeth as a personal catastrophe with the implication of old age and physical deterioration associated with it. If the patient has been under severe nervous tension for a long time and his emotional state is nearing the point of exhaustion, no radical procedures in oral rehabilitation should be undertaken. The load placed upon the patient's psyche by the sudden transition from a natural dentition to an artificial one may overtax his emotional reserve capacity. A nervous breakdown may ensue. In this type of differential diagnosis as, indeed, in all his professional work, the dentist must possess not only a vast amount of scientific knowledge and an investigative mind but also a kind and sympathetic heart. The patient's fears, anxieties, and general emotional insecurity rate as much consideration as the state of health of his heart and circulatory system. *The total personality of the patient must be treated with sympathetic understanding.*

HISTOLOGY AND PHYSIOLOGY OF THE ORAL MUCOSA

Since the palatal vault and alveolar ridges form the very foundation of the artificial dentures it is essential that we have a working knowledge of the topography, morphology and histology of these structures. In the edentulous mouth the oral mucosa is the first structure under observation. The oral mucosa may be divided into three distinct types, each having its own peculiar pattern of function depending upon the area it covers: (1) the masticatory mucosa, (2) the lining mucosa, and (3) the specialized mucosa.

The Masticatory Mucosa. This covers the palatal vault and the alveolar ridges, upper and lower, and is directly and rigidly attached to the periosteum of the underlying bony structures. It derives its name *masticatory* from the fact that, in the presence or absence of the natural teeth, this portion of the oral mucosa bears the brunt of pressure and friction during the process of mastication. When one is masticating with the natural teeth, the food slides off their occlusal surfaces onto the buccal and lingual mucosa of the alveolar ridges. Some periodontists attribute therapeutic value to the resultant friction against the gingiva and alveolar mucosa. They feel that this friction, massaging the gingiva, stimulates the blood circulation to the enhancement of good health. I am in complete accord with the periodontists in this respect and would go one step further. I would advocate and encourage the use of hard foods not alone to enhance good health in the periodontal structures but also to enhance the blood circulation

and a higher degree of hornification of the entire oral mucosa. The higher the degree of hornification of the masticatory mucosa, within physiologic limits, the better will be the seating surface that it will afford for the artificial dentures, all other conditions remaining equal.

The Lining Mucosa. The outstanding characteristic of the lining mucosa is that its epithelium is thin, little or not at all hornified and the lamina propria is also thin. The lining mucosa in various zones of the oral cavity differs in the structure of its submucosa. Where the lining mucosa covers muscles such as the buccinator on the cheeks, orbicularis oris on the lips, etc., the mucosa is immovably attached to the fascia of the muscle it covers. The mucosa itself, however, is usually highly elastic in these regions. In some instances the lining mucosa lacks the submucous layer altogether, as in the undersurface of the tongue; in other zones the submucosa is loose and of considerable volume and is loosely and movably attached to the deep underlying structures, as in the fornix vestibuli. These characteristics of the lining mucosa safeguard it from injury by the various movements of the muscles to which it is attached, and prevent the formation of mucosal folds and wrinkles that might be caught between the teeth during mastication and speech production. With the approach of old age and its concomitant lack of elasticity and turgescence of the mucosa, the liability to tongue and cheek biting increases.

The Specialized Mucosa. This type of oral mucosa represents the covering of the dorsal surface of the tongue, which is a highly specialized organ—hence its designation *specialized.* The dorsal surface of the tongue is rough and irregular and is second highest in degree of hornification of its epithelial covering. A V-shaped line is situated between the anterior two-thirds of the tongue, the body, and the posterior third, the base. A great number of specialized papillae can be observed on the upper surface of the tongue.

THE ORAL MUCOSA FROM A CLINICAL STANDPOINT

Color of the Oral Mucosa

The color of the oral mucosa varies so widely in different individuals, in different locations of the oral cavity of the same individual, and at different times of the day under variations of light refraction that the best method of learning the difference between the normal and abnormal color of the oral mucosa is by clinical experience. To state that the most characteristic color of the oral mucosa is pale pink is not very helpful to the student or dental practitioner, because the oral mucosa may be red or pink or very pale and still be normal. The color

of the mucosa will depend in great measure upon the relative position the vascular network occupies and upon its degree of vascularity.

1. The vascular network may be deep or superficial. If the blood vessels are located deep in the submucous layer the mucosa will look pale. On the other hand, if the same network of blood vessels is located nearer to the surface the mucosa will look deep pink or red.

2. If the degree of vascularization is pronounced, the mucosa will manifest a pink or reddish color. If, on the other hand, the vascular network is scanty the mucosa will be pale pink or pale.

3. The hemoglobin itself may vary greatly within physiologic limits.

4. The chemical composition of the oral epithelium may alter the transparency of the mucosa—and with it its color.

5. The degree of thickness or thinness of the mucosal connective tissue layer in different parts of the oral cavity will affect the color of the oral mucosa.

The reader can easily see what a multiplicity of color schemes all these factors may bring about, and yet all of them may be within physiologic limits. To be able to differentiate the normal from the abnormal color of the oral mucosa one must have a good working knowledge of the anatomy, histology and physiology of the masticatory mechanism, reinforced with extensive clinical experience.

Thickness of the Oral Mucosa in Relation to Denture Retention

The oral mucosa may be too thick, of average thickness, or excessively thin.

The Excessively Thick Mucosa. If the oral mucosa is too thick it will be difficult to obtain adequate retention, the degree of difficulty depending upon the extent to which the thickness is excessive. Excessive thickness is usually dependent upon the relative thickness of the connective tissue in the lamina propria as well as in the submucosa. If this type of oral mucosa is overcompressed by the particular impression technique employed by the operator it will have a tendency to return to its original position, thereby displacing the denture. Should the operator resort to the use of the mucostatic technique, the overcompression of the mucosa in the process of mastication will evoke the same reaction with displacement of the artificial denture resulting therefrom.

Excessive thickness of the mucosa has a more adverse effect upon retention of the upper than of the lower denture. The reason for this lies in the fact that, in addition to the excessive thickness of the connective tissue layer of the lamina propria, the palatal vault has a fatty layer anteriorly and a glandular layer posteriorly. The combined

thickness of the tissues covering the anterolateral and posterolateral areas of the hard palate likens it to the thickness of the subcutaneous soft tissues of the palm of the hand. These soft tissues, when overcompressed, tend to return to their original position and in this way loosen the upper denture. This type of excessively thick oral mucosa is usually observed in mouth breathers where the palatal vault is high and V shaped, with the apex upward.

The Excessively Thin Mucosa. From a differential diagnostic standpoint, the extremely thin oral mucosa is just as unfavorable as a foundation for artificial dentures as is the excessively thick mucosa. In some instances the mucosa is so thin that the bone under it is almost showing through. This type of mucosa is thin and unyielding, parchment-like in appearance and very pale in color. In order to develop intimate contact with good retention between the denture and the mucosa, the latter must be compressible to some small degree to allow for corresponding uniform initial settling of the dentures under balanced occlusion. A mucosa in which the connective tissue layer is very thin does not possess the slight yielding quality required for this type of settling. In addition, a denture resting on an excessively thin mucosa is more apt to cause discomfort and pain than a denture whose basal seat is slightly yielding under masticatory stress. We thus arrive at a conclusion that, from a differential diagnostic standpoint, the mucosa of average thickness and average consistency (see below) is the most favorable for denture retention and denture stability.

Consistency of the Oral Mucosa in Relation to Denture Retention

The consistency, i.e., the density, elasticity or viscosity of the masticatory mucosa, depends to some extent upon the manner of its attachment to the underlying periosteum. A mucosa that may be considered of average consistency clinically and which covers the alveolar ridges with the same homogeneity throughout may be regarded as favorable for retention of artificial dentures. The histologic prototype of such a clinical pattern of alveolar mucosa is one in which no distinct submucous layer can be recognized and in which the papillary and reticular layers of the lamina propria are well balanced. A mucosa covering the alveolar ridges that is lacking in uniformity of thickness with thick and thin islands dispersed in various areas represents a negative feature from the standpoint of denture retention, all other conditions remaining equal.

A differential diagnostic study of the mucosa covering the palatal vault in relation to the retention of the upper denture must take several additional factors into consideration. In the first place, the palatal

mucosa has a submucous layer by means of which the lamina propria is attached to the periosteum. This submucous layer is subdivided into irregular intercommunicating compartments of various sizes which, as mentioned above, contain adipose tissue in the anterior part of the hard palate and glands in the posterior part. The cushioning effect of the fat or glands in the submucous layer is like that of the palm or the sole.

It must be here pointed out that the median raphe of the palatal vault is devoid of the submucous layer and the mucosa is usually very thin in this area. To assure uniform settling of the upper denture which, in turn, leads to intimacy of contact between the denture and the mucosa and with it to better retention, the median raphe should be relieved either in the impression, on the cast or in the completed denture. However, the entire stretch of the palatal vault from the median raphe to the alveolar process on either side is covered with a mucosa that has a fat- or gland-containing submucous layer. If both the adipose and glandular tissues are present here in average amounts it presents a favorable feature for retention of the upper denture. If these tissues are present in excessive amounts the prognosis for retention is unfavorable. Whether we are dealing with the palatal mucosa, attached to the periosteum by means of the submucous layer, or the alveolar mucosa, attached to the periosteum by means of connective tissue fibers directly from the lamina propria, the connection must be firm if it is to form a favorable seating surface for the denture. Frequently, however, the mucosa is found to be loosely connected to the periosteum. This is observed in instances of severe chronic suppurative alveoloclasia that has persisted for a long time prior to the removal of the natural teeth, or when wearing artificial dentures has caused severe trauma to the periosteum. In either case, the connection between the mucosa and periosteum will have been severed to a greater or lesser extent. This looseness of the mucosa has a very unfavorable effect upon the stability of the artificial dentures. The prognosis in such cases should be guarded, not only because a loose mucosa forms a poor basal seat for the artificial denture but also because a denture in function under these conditions causes friction of the under surface of the mucosa against the periosteum, resulting in discomfort and pain.

Another type of loose and flabby mucosa that has a very unfavorable effect upon the stability of the dentures, particularly the upper, is that which occurs in the anterior segment of the maxillary alveolar ridge. In instances in which the complete upper denture functions in conjunction with a lower partial denture, where the natural lower anterior teeth are present and cause severe trauma to the anterior seg-

ment of the upper alveolar process, the latter soon completely resorbs and the mucosa hangs loosely downward. When even slight occlusal pressure is exerted by the lower partial denture against the complete upper denture, the latter tends to slide off its basal seat in a forward direction. In this way the occlusal relationship between the two dentures completely deteriorates and more resorption of the upper alveolar process follows. In addition, this situation is usually aggravated by the fact that in the process of construction of such dentures it is extremely difficult to obtain a correct centric jaw relation because of the tendency of the upper denture to glide forward at the slightest occlusal contact with the lower denture.

RELATION OF ALVEOLAR ARCHES TO DENTURE STABILITY AND RETENTION

The stability and the retention of artificial dentures are reciprocally interdependent and synergistic. Though each of these factors in denture prosthesis has its own distinct definition, we prefer to treat them here together. Stability and retention are affected by both the size and the shape of the alveolar arches.

Size of Alveolar Arches

The size of the alveolar arches has a direct relation to the stability and retention of the upper and lower dentures. If the arches are excessively large or excessively small, they are usually not favorable for stability and retention. The average-size dental arches are usually the most favorable for denture success, all other conditions remaining equal. The accepted concept in denture prosthesis that the larger the area covered by the denture the better the retention holds true only up to certain limits. It seems that while the larger area covered by the denture does afford better retention, the concomitant increase in ligamentous attachments peripheral to the denture border has an adverse effect upon retention and stability. Where the alveolar arch is too small, inadequate retention is the rule, because the smaller the area covered by the denture the smaller is its adhesive force.

Shape of Alveolar Arches

The shape of the alveolar arches also has a definite relation to denture stability and retention. The square type of alveolar arch is the most favorable for denture retention and stability, all other conditions remaining equal. The ovoid form of alveolar arch rates next in this

respect. The tapering alveolar arch is the least favorable of all for stability and retention. The square type of alveolar arch locks or immobilizes the artificial denture, thereby contributing to its stability and retention. The other two arch forms—the ovoid and tapering—do not possess this quality to an equal degree.

RELATION OF ALVEOLAR RIDGES TO DENTURE STABILITY AND RETENTION

Size of Alveolar Ridges

The excessively large and excessively small alveolar ridge presents a condition that is unfavorable for denture retention. The average-size ridge is the most favorable and conducive to best results from a diagnostic standpoint. The excessively large alveolar ridge presents unfavorable conditions for artificial dentures in several ways.

1. It makes the lips bulge anteriorly, which is unsightly from an esthetic standpoint.
2. It reduces the intermaxillary space so that there is little room for the artificial teeth.
3. The excessively large upper alveolar ridge obliterates a greater part of the palatal vault, thereby reducing the retention of the upper denture.
4. If the lower alveolar ridge is excessively large, the lingual flange of the lower denture is built almost entirely at the expense of the patient's tongue space. The crowded tongue tends then to unseat the denture by lifting it up from its basal seat.
5. By the same token, dentures constructed upon excessively large ridges frequently handicap the patient's speech production.

Shape of Alveolar Ridges

A square type of alveolar ridge in vertical section is more favorable for retention and stability than the ovoid and tapering types, because the square type affords more area to be covered by the denture and the flat crest of such a ridge presents a better seating surface for the denture. It follows, then, that the extremely tapering alveolar ridges present great difficulties for stability and retention of artificial dentures. This type of sharp, knife-edge alveolar ridge further complicates the situation by the fact that the mucosa on the crest of the ridge is enclosed between the sharp bone underneath and the rigid denture above. The artificial denture in function causes friction of the undersurface of the mucosa against the sharp alveolar crest, inflicting severe

pain on the patient. The prognosis in such cases should be guarded even when extreme precautions are taken in management, i.e., relieving the crest of the ridge, using artificial teeth with a narrow buccolingual diameter and keeping the occlusal surfaces of the posterior teeth as close to the crest of the ridge as possible.

Extremely Flat Maxillary Alveolar Ridges and Shallow Palatal Vault. A flat palatal vault with average-size alveolar ridges may usually be considered as a combination that indicates a favorable prognosis for retention and stability of the upper denture. However, if these ridges have undergone considerable resorption to a point that

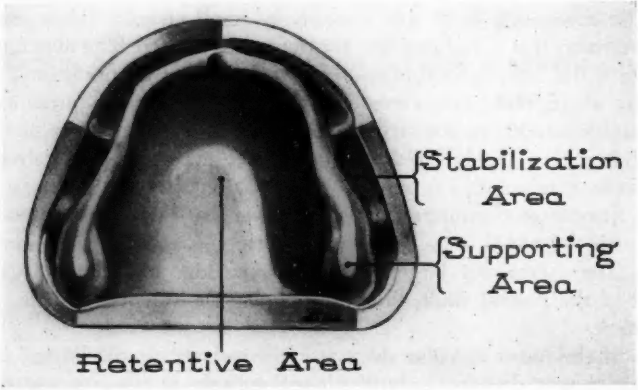

Fig. 1. Palatal vault showing retentive area, supporting area, and stabilization area.

they are almost leveled off with the palatal vault, the prognosis for retention will still remain favorable but the chances for denture stability become extremely poor. Generally speaking, as far as the upper denture is concerned, it derives its retention from the palatal vault and its stability from the alveolar ridges (Fig. 1). When the latter have undergone complete resorption, the denture commences to move in function at the slightest provocation. The situation becomes further complicated by the fact that the correct recording of the centric jaw relation in such instances becomes extremely difficult, if not impossible. Even slight contact of softened wax occlusal surfaces of the occlusion rims makes the upper occlusion rim shift forward. Under these circumstances it is impossible to establish harmony between centric occlusion and centric jaw relation. A similar situation prevails when there is a great deal of flabby tissue in the anterior segment of the maxillary alveolar ridge with very shallow or no maxillary tuberosities. These cases present greatest difficulties to the prosthodontist and

general practitioner alike. At times the nurse may have to assist in maintaining the upper occlusion rim in position while the centric jaw relation is being recorded. The thing to bear in mind in differential diagnostic studies of this type of case is that the upper denture will usually stay securely in place during phonation and speech production but will tend to shift and be dislodged during mastication of even soft foods.

Extremely Flat Mandibular Alveolar Ridges. The average flat lower mandibular ridge, if properly outlined to include as much area coverage as possible, does not usually represent great difficulties in securing fair stability and fair retention. The basal seat should be extended buccally up to the external oblique line and the latter may also be included, if need be, provided its muscle attachments are not tense. In the anterior segment in the region of the orbicularis oris muscle the labial flange should be extended to include the neutral zone between the masticatory mucosa of the alveolar process and the lining mucosa covering the inner surface of the lip. Lingually, on the other hand, the basal seat should cover the mylohyoid ridge and extend into the neutral zone of the lining mucosa as far as the average physiologic activity of the palatoglossus, mylohyoideus and genioglossus muscles will permit. By this description we mean covering as much denture-bearing area as possible without impinging upon tense ligamentous attachments.

A flat lower alveolar ridge with an outline of the denture-bearing area as above described should make a good foundation for an artificial denture. Of course, for ultimate success in complete denture prosthesis we must always strive for balanced occlusion and balanced articulation. It is common knowledge today that the strongest and best alveolar ridges will deteriorate in the worst way under the impact of traumatic occlusion resulting from lack of association of a correct centric occlusion with a correct centric jaw relation. The diagnostician must be aware of this important fact when he studies the edentulous mouth to establish a diagnosis.

FORAMINA AND THEIR CONTENTS IN RELATION TO EXTREMELY RESORBED ALVEOLAR RIDGES

The anterior palatine foramen is situated immediately behind the upper incisor teeth. From this foramen two canals branch off laterally to the right and left nasal fossa (the foramina of Stenson) and two lie in the mid line, one in front and one behind (the foramina of Scarpa). Through the foramina of Stenson pass the anterior or terminal branches of the descending or posterior palatine arteries, which

ascend from the mouth to the right and left nasal fossa. The foramina of Scarpa transmit the nasopalatine nerves, the left passing through the anterior and the right through the posterior canal. A burning sensation of the oral cavity or continuous smarting in the nostrils is a frequent concomitant of excessive pressure exerted by the dentures upon this area. The anterior palatine foramen should, therefore, be carefully relieved either in the impression or on the cast in order to prevent, whenever possible, such syndromes from occurring.

The mental foramen is situated below the level of the apices between the two lower bicuspid teeth and transmits the mental vessels

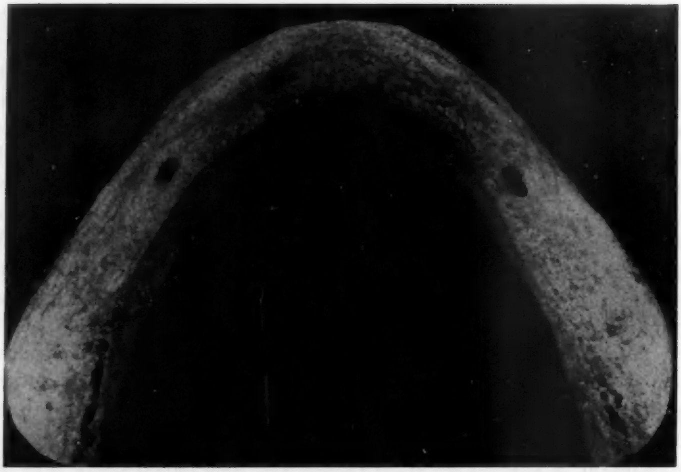

Fig. 2. Photograph showing position of mental foramen in excessively atrophied mandible.

and nerve. The mental vessels branch off from the inferior alveolar artery, a branch of the internal maxillary. The mental nerve arises from the inferior alveolar nerve, a branch of the third division of the fifth nerve. The mental artery escapes with the nerve at the mental foramen, supplies the structures composing the chin, and anastomoses with the submental and inferior labial arteries. The mental nerve emerges from the bone at the mental foramen and divides into two or three branches; one descends to supply the skin of the chin and another (sometimes two) ascends to supply the skin and mucous membrane of the lower lip. These branches communicate freely with the facial nerve.

When considerable resorption of the alveolar process has occurred, the mental foramen becomes exposed in an upward direction (Fig. 2).

On digital examination of this area we frequently palpate a nodule 2 to 3 mm. in diameter which moves freely in all directions at the slightest contact with the operator's finger, evoking a severe reaction of pain. The latter is usually described by the patient as a combination of pain in the oral cavity and a sensation of numbness in the lower lip and chin. The area of the nodule should be carefully relieved in the impression, on the cast or in the completed denture; this has in many instances been accompanied by a relief of the symptom of numbness in the lip and chin.

RELATION OF ASCENDING MANDIBULAR RAMI TO LOWER DENTURE STABILITY

We frequently encounter lower alveolar ridges that appear to be favorable as a basal seat for lower dentures, yet on completion of these dentures we find them to be completely lacking in stability. There are, of course, many reasons that may account for this situation. However, we are presently interested in the particular relationship between the mandibular rami and their alveolar ridges that may influence the stability of the lower dentures.

The relationship of each ramus to its respective alveolar ridge can best be studied clinically by digital examination. On guiding the index finger along the crest of the ridge in a posterior direction, the finger may come in contact with the lower portion of the ascending ramus, which acts as a bulwark preventing the finger from sliding backward. This anatomic relationship between ramus and alveolar ridge is favorable for denture stability because the retromolar triangle and the lowest portion of the ascending ramus adjacent to it prevent the lower denture from sliding backward, making it more stable. This particular relationship between rami and alveolar arches in the edentulous mouth is a pattern that usually follows a natural dentition in which the first, second and third molars were running likewise, i.e., backward and laterally. However, if on guiding the finger carefully and lightly along the crest of the alveolar ridge in a posterior direction, the finger slides medially and falls off into the oral cavity proper at the lateral border of the tongue, we may assume with a great degree of probability that denture stability will not be at its best. This latter type of ramus-ridge relationship is a pattern that usually follows a natural dentition in which the last three molars were crowded considerably lingually. The alveolar arch in this instance is also crowded lingually, and the posterior border of the lower denture following in the same direction does not effect proper contact with the ascending ramus. It is understood that the ramus-ridge relationship just de-

scribed does not in itself always spell success or failure of the lower denture. It is just one more feature that is either favorable or unfavorable and as such may well be the straw that breaks the camel's back.

RELATION OF SALIVA TO DENTURE RETENTION

The salivary glands are under the control of the autonomic (involuntary) nervous system. They receive fibers from both the sympathetic and parasympathetic divisions. Stimulation of the latter causes in most animals a profuse salivation, watery in consistency, whereas stimulation of the sympathetic fibers causes a scanty secretion of a thick, mucinous fluid. We may then conclude that the sympathetic fibers innervate the mucous cells, and the parasympathetic, the serous cells.

From time to time we encounter two edentulous cavities that appear to be identical from every standpoint. We follow the same procedure in the management of the two patients, giving them identically the same attention. Yet on completion of our work, we find that one set of dentures possesses excellent retention while the other is completely lacking in retention. It is possible that the difference in the physical and chemical properties of the two kinds of saliva is the answer to the riddle.

Test tube analysis of the saliva is as yet of little help to us in our everyday work in the construction of complete dentures. The keen diagnostician, however, will observe clinically some differences related to quantity and quality of saliva. Sialism, or an excessive flow of saliva, interferes with denture retention. Xerostomia, or dry mouth, is even less favorable for the retention of artificial dentures. On careful digital examination of the oral mucosa we at times find it so smooth that our index finger is just slipping. This is the so-called slippery mucosa, which is probably caused by an excess of mucin in the saliva and is very unfavorable for denture retention. There is also the ropy saliva, in which there is complete predominance of mucin over all other components and which considerably interferes with denture retention. The ropy saliva places itself between the mucosa and the denture, thereby preventing their intimate contact. Lack of intimacy of contact between the denture and the mucosa reduces the adhesion and with it the retention.

SUMMARY

1. In evaluating the edentulous oral cavity for prosthetic restorations it is essential to have a basic knowledge of the topography, morphology, histology and physiology of the organs and tissues involved.

2. The size and shape of the maxillary and mandibular alveolar ridges, the thickness, density and turgescence of the oral mucosa and the degree of its physiologic keratinization, and the nature of the saliva all influence success or failure in the construction of complete dentures.

3. The general health and age of the patient as well as the functional reserve potential inherent in the edentulous mouth also play an important role in prosthodontics.

4. The physiologic retrogressive changes that usually run parallel with senescence should also be taken carefully into consideration in diagnostic and prognostic studies of the edentulous masticatory mechanism.

136 East 54th Street
New York, New York

Diagnostic Factors Which Influence the Choice of Posterior Occlusion

S. Howard Payne, D.D.S.*

"I can eat anything!" says one patient. "I can't bite a marshmallow!" says another. These are exact quotations from two of the author's patients. The first is a very stable, healthy, intelligent woman in her late seventies. The second is a chronically ill, emaciated, emotionally tense individual in her early fifties who has a sore mouth and resents it. She also resents the constant medical care she has to have and has the philosophy, "why does this have to happen to me?" These overly indulged, self-pitying individuals are all too common. Ordinarily, we think of advanced age as a handicap to adaptability but here we see two patients who represent contradictory extremes of the prosthetic problem but serve to illustrate *one of the most important factors of all;* that each patient is an individual and must be treated accordingly.

Research, study and observation sometimes attempt to group too much, to generalize too freely and to place many humans in the same barrel categorically speaking. This is wrong. We must learn to recognize the differences in our patients, and we must learn the techniques of fitting not only the mouths of our patients but the minds as well.

Now, what do we mean by an ideal posterior occlusion? We have a space between the ridges, into which we must orient comfortable, well fitting, efficient dentures that are also pleasing in appearance. The size, form and arrangement of the teeth are governed by many factors. Few would bother to purchase or to wear dentures if the desire to look better or younger were entirely absent. Except for small boys and old men, it is very normal to want to look our best.

We must determine the correct vertical dimension, the contour and width of the arches, the tissue variation on the supporting areas of the ridges and the proper restoration of matrix to the muscles of expression and the structures immediately adjacent to the residual ridges. The patient who is ready for dentures and who has a few natural

* Assistant Dean and Professor of Prosthodontics, University of Buffalo School of Dentistry.

teeth left is giving us much valuable information about arch width, occlusal plane, tooth position and possibly vertical dimension. Although these teeth may have moved out of their original position by extrusion or lateral movement, we are still able to calculate the original positions more accurately than by merely seeing the residual ridges. We should not fail to make study casts and measurements before extraction and then see that this information is utilized, especially if a technician is going to set the teeth. Photographs are also a valuable part of these pre-extraction records.

To add to the complexities, most dentists have learned that the tissue covering the ridges is not constant either in volume or resistance. The saliva which constitutes the adhesive film holding the dentures in place is not the same in quantity or consistency at all times. When one is asleep, there is less saliva and greater tissue volume because of the increased supply of blood to the head while lying down. Dentures, therefore, are tighter when one is recumbent or in the morning immediately upon arising. By five o'clock in the afternoon, however, more fluid has migrated to the lower extremities, the blood sugar level is low, and the dentures become loose and bothersome because of the decreased volume and resistance of the oral tissues. It is really remarkable that we can build the dentures at all on such an elusive foundation.

In addition to these physiologic variations in the tissue, there are age factors, nutritional, pathologic, and stress factors which also affect the fit and comfort of our dentures. It should be made quite clear to the patient that there is much more involved in successfully wearing dentures than the fabrication and delivery of a "piece of hardware."

PSYCHOLOGIC AND SYSTEMIC FACTORS

To get down to practical examples, suppose the receptionist seats a new patient in the chair for consultation about new dentures. We greet her and then say, "Tell me about your denture problem," or "Tell me about your mouth." This gives the patient an opportunity to tell her story while we are scrubbing or listening as we stand at the chair. As this recitation is going on, we try to evaluate the type of person with whom we are dealing:

1. Is the story logical, reasonable and to the point or highly colored, emotional and without continuity?

2. Does the patient twist her hands or fidget a good deal? Is there a twitch or tremor about her face or the rest of her body?

3. Is the patient very critical of the dentists who have done her work previously? Is she dressed to an extreme standard of perfection,

with every hair in place and make-up just so? Here you will find a perfectionist, difficult to satisfy unless the work is also just exactly so.

The characteristics just mentioned can be observed early in the interview without awareness on the patient's part. Thin, high strung, restless and highly emotional persons comprise the majority of our problem patients, and we must learn to recognize the type before starting the work.

Now we can observe the patient as we examine the mouth. Are the skin and the mucous membrane pale? Suspect anemia. A sore tongue is also a prominent symptom of anemia.

Does inflammation exist on the ridge surfaces or are the gingivae swollen and translucent? A high blood sugar or possible diabetes can be expected. Angular cheilosis (sores at the corners of the mouth) and a history of chronic soreness of the gums indicate vitamin deficiency which will be improved by prescribing B complex and ascorbic acid. Hydrocortisone acetate ointment has been used with some success.

Pyorrhea, leading to the loss of the teeth, often accompanied by arthritis, and subsequent rapid resorption of the bone with chronic sore mouth afterward under complete dentures is a common syndrome. This should be recognized early so that the patient is aware of the difficulties to come. Of course, there are many oral indications of specific diseases for which the dentist should always be on guard, and careful examination is imperative. The diet and fluid intake are extremely important and should be checked by the prosthodontist almost without exception. It is startling in these modern times and with our high standard of living how inadequate is the diet of the average denture patient.

A case history chart is valuable in obtaining all the information about the patient, but the personal, "homey" chat should not be discarded for the monotonous impersonal question-droning routine. The denture patient *must* be made to feel the dentist's interest in the problem. By now the patient should begin to realize that he is the foundation underneath the dentures and that the health and form of the oral structures which he brings to the dentist have a good deal to do with his relative success with dentures. How few people know, without telling them, what dentures are really like! Do not keep them in ignorance and have to make excuses later.

MECHANICAL AND PHYSIOLOGIC FACTORS

So far, we have been trying to determine data about the patient's psychologic state, his systemic or possibly pathologic state, and now we must consider the mechanical and physiologic aspects.

Our denture foundations consist of certain areas of the maxilla and mandible. The maxilla is blessed with a large vault area which has not been occupied by natural teeth (except on occasion by impaction) and is less changeable than the ridge area, which is largely cancellous bone. The mandible has its best supporting area in the buccal shelf just lateral to the molar teeth and extending outward to the external oblique line. The adjacent retromolar pad area is extremely important and must be covered. The upward slope of the ramus distally provides bracing for the lower denture and the pad can be used as a landmark in locating the occlusal plane posteriorly. Over the bone of both ridges exists a covering of connective tissue and stratified squamous epithelium of varying thickness and resiliency. When bone resorption is excessive, the tissue does not necessarily shrink in conformity but will often exist in flabby, loose rolls which provide a very unsatisfactory foundation. This excess tissue should almost always be removed surgically.

Mandibular Movements

The mandible is a movable member whose condyles function in the glenoid fossae of the temporal bones. Each condyle articulates with an interposing meniscus in a very complex type of joint. The mandible can move from side to side and forward and backward, and can open and close including all motion in between. A three dimensional graph of all possible mandible movements is sometimes called the "envelope of motion" because of its pouch-like appearance. One movement of which the mandible is capable is many times overlooked or forgotten by the busy dentist. This is the ability of the mandible to move up and down unilaterally. For example, if a match stick is placed between the molars on the right side and pressure is applied, the teeth can be made to almost touch on the left side. This is referred to as Boswell's movement and is very important and significant when registering various occlusions. It is the explanation of why a unilateral "bite" for a bridge or inlay will result in a finished restoration that is too high and needs to be ground considerably to get it into proper occlusion. It also explains why we must use utmost caution to place media of uniform consistency bilaterally when recording any maxillomandibular relationship. If one side offers more resistance than the other, the mandible closes with more force on the resistant side and Boswell's movement will make an accurate record impossible.

The retruding mandible is the most difficult because we have such a small mandibular ridge opposing a normal or large maxilla. The

anteroposterior relation makes it difficult to centralize biting forces where we want them.

The protruding mandible is just the opposite, and frequently makes a problem denture out of the upper. Here all the pressure tends to fall on the anterior third of the upper denture, tipping it loose or causing rapid bone destruction.

It is important to remember that speech, respiration, and the maintenance of the normal lengths of the muscles of expression are all part of the functioning of the teeth and mouth. Teeth bear definite relationships to all oral structures. We must not overlook normal function and position.

The Alveolar Ridge

The type and size of each ridge is very important in planning the occlusion. The ridge relation can either complicate the problem or make the prognosis favorable. The ideal, of course, is to have broad, fairly prominent ridges with vertical sides and good maxillary tuberosities. The ridges should be directly over one another anteroposteriorly and laterally, with about one-half inch of interridge space and the ridge crests approximately parallel to one another. Deviations alter the problem so the ridge relation should always be checked. One good way is to have the patient close lightly on the dentist's thumb, which is an average interridge distance, and then to examine the relationship with the above criteria in mind.

Types of Occlusion

Much has been written about posterior tooth selection and arrangement, and at the present time there is a good deal of discussion about (1) bilateral balanced occlusion, (2) unilateral balanced occlusion, and (3) functional or physiologic occlusion.

Bilateral balanced occlusion is the classic concept in which interdigitation of cusps exists and there are multiple contacts on both sides in all eccentric excursions. Cusp teeth are set in definite relation to one another (see Fig. 1), and all teeth should intercuspate and touch simultaneously when the mandible closes in centric relation. This is called "balanced centric occlusion." In right lateral movements, on the right side or working side, the upper and lower buccal cusps are touching and the upper and lower lingual cusps are touching. On the left or balancing side, the upper lingual cusps are just touching the lower buccal cusps. In straight protrusion the forward-sloping inclines

of the lower posterior teeth slide forward on the backward-sloping inclines of the upper teeth to reach a tip to tip relationship which is "balanced protrusive occlusion." The ability to move from one balanced occlusion to another is sometimes called "balanced articulation."

Unilateral balanced occlusion consists in arranging the teeth slightly lingual to the ridge crest or arranging the occlusal inclines so that the force falls to the lingual or palatal side of the ridge. The theory is shown in Figure 2. A unilateral balance is not always possible without encroaching on normal physiology. The tongue should not be crowded excessively nor should the phonetic factors be overlooked in developing mechanics without regard for all factors.

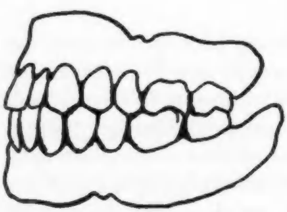

Fig. 1.

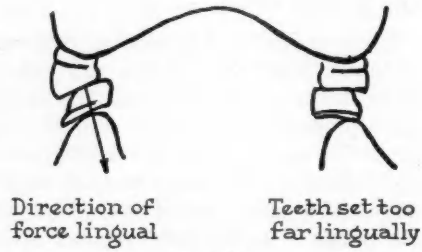

Fig. 2.

The so-called *functional occlusion,* which is highly touted, much maligned and perhaps little understood by some, is really not a separate occlusion at all but includes a masticating cycle ending in an occlusal relationship which it is hoped will be balanced centric occlusion. Some even say there is no contact, but eventually the bolus of food is penetrating and the teeth do come together.

Balanced occlusion in eccentric positions has very little to do with mastication. Most dentists have had at least one patient who wore the "old upper" with the "new lower" or vice versa. In many instances the efficiency in chewing was much better because of smaller contacts and more spaces or sluicing. An occlusion which is too intimate is not efficient, which is the reason acrylic posteriors "wear into" poor efficiency. They simply lose their escapeways!

The Chewing Cycle

The chewing cycle as we know it from the work of many investigators is shaped somewhat like a teardrop as viewed standing in front of the patient. As the mandible opens to the required distance it moves

laterally and then closes toward the midline. As viewed from the side the jaw will move slightly backward. This picture is quite typical if observed in a young, normal individual, especially one with his own teeth, chewing a nonresistant food. If the act of incision is brought in, or if the bolus is resistant, then of course the chewing cycles will vary erratically. However, the typical teardrop graph may also change from person to person. It can be shown that some do not close to quite a position of sharp midline and centric relation but instead have an area of contact. Some chewing cycles are even flat on top for the width of the occlusal surfaces of the teeth, but this is not common. It is again an individual situation depending on the fineness of neuromuscular agility as influenced by proprioceptive control or guidance. In older people, centric relation as registered on a tracing plate may well require an area instead of a point. Therefore, we believe that teeth should be set with ample freedom in centric occlusion. If the cusps are too steep, or if the intercuspation does not fall properly in the arc of closing, then there will be interference and horizontal shifting of the bases in masticating when the terminal portion of the stroke is reached. Thus, the teeth must be ground carefully so that in closing to centric occlusion, as in a masticating stroke, there will be no interference and the teeth will touch simultaneously in their primary contact.

We have said that the ability of the teeth to move smoothly over one another on an articulator has nothing to do with mastication in the true sense. The question arises, are these lateral and protrusive balances necessary in a set of artificial dentures? In many individuals we can say emphatically, "yes!" In others, "no." Always look at the old dentures worn in the mouth (or pocketbook) of the prospective patient! In good light by twisting and turning them, look for the facets which will shine like cut glass! It makes little difference whether we choose to call this grinding of the teeth together by the name "bruxism," "denture play," "night grinding," or "pathologic grinding." The point is, it exists very frequently and our set-ups must allow for it. To set cusps interdigitated precisely will only prevent the bruxism at the expense of shifting of the bases and excessive resorption.

VARIATIONS

We have now talked about the systemic, psychologic and physiologic factors and have tried to differentiate certain concepts of occlusion. Now how should we put this knowledge to use?

The patient who is highly emotional, restless and usually thin will react to much less intense stimuli and, therefore, will be bothered more by dentures as well as by frequent and sometimes chronic sore-

ness. One illustration which can be easily understood by a patient is to imagine herself sitting alone at midnight reading a very scary mystery novel while the wind howls and the house creaks. The slightest touch on the shoulder would be enough to send her screaming into the air! However, on a warm, sunny terrace at noon, the same touch would scarcely elicit the turning of the head. Thus the patient can understand the desirability of relaxation and serenity and will make an honest attempt to attain these qualities. Proper diet and vitamin therapy are important because these tense patients burn up great quantities of proteins and other nutrients.

The mild psychoneurotics or the unhappy, shy individuals need interest, reassurance and confidence. They cannot be handled well in a cold, impersonal manner.

The more serious neurotics, particularly of the paranoid type, are very difficult and often cannot be reached at all. They dare the dentist to help them or else are sure he is trying to cheat or trick them.

In choosing an occlusal scheme, we must be careful to stay within the scope of the normal physiology of mastication and phonation. The tongue space should not be encroached upon routinely to "get the teeth inside the ridge." The anterior teeth should not necessarily be set "on the ridge," which many times turns out to be far inside where the natural teeth grew. It is a good rule to set the teeth approximately where the natural teeth grew. If the natural teeth are malpositioned or ugly in appearance, corrections, of course, should be made, but not at the expense of normal physiology. One such common error is to perform radical alveolectomy on a protruding maxilla and set short artificial teeth inside the upper ridge. This collapses the muscles of expression and creates a severe phonetic problem. The incisal edges could be brought back and shortened slightly, but the necks of the teeth and the labial flange of the denture should support the lip almost as before.

Now from a mechanical standpoint we need to look at the ridges for prominence, length, tissue covering, ridge relation and interocclusal space at the "ideal" or "normal" vertical dimension. If our patient is a "grinder" we must plan on freedom of movement and bilateral contacts. The free movements of the mandible describe an upward arc (see Fig. 3). If the ridge is very flat the introduction of cusp heights will create excess horizontal movement when bruxing and produce excessive resorption. Freedom from interference when sliding the teeth on one another is desirable in these individuals. On the other hand, the prognathic patient, or the stable, stolid, easygoing individual usually can accommodate to less freedom of occlusion. We believe, in effect, that occlusion is a matter of degree; some individuals need the

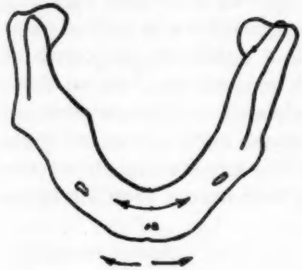

Fig. 3.

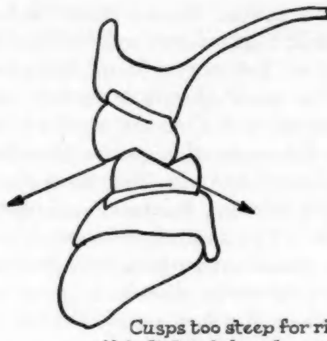

Fig. 4.

ultimate in refinement; others can get along perfectly well with a minimum of effort.

Selection of Posterior Teeth

Types of posterior teeth should be chosen to fit the patient's needs (see Table 1). Where indicated, cusp teeth whose anterior-posterior

TABLE 1. *Guide for Posterior Tooth Selection*

RIDGE TYPE	INTERRIDGE DISTANCE	RIDGE RELATION	TYPE POSTERIOR
1. Prominent	Short or ideal	Normal	Cusp
2. Prominent	Average	Prognathous	Cusp
3. Prominent	Average	Orthognathous	Noninterdigitated cusp teeth, Pleasure modification or flat
4. Flat, i.e., extreme resorption	Great	Normal	Flat
5. Flat	Great	Prognathous	Nonintercusping cusp
6. Flat	Great	Orthognathous	Flat
7. Prominent or flat	Varied	Abnormal or deviated	Flat

Note: The particular flat forms selected should be governed by type of musculature and diet. For example, a husky male with well-developed muscles of mastication who eats steak will do well with steel insert teeth. A frail little woman who exists on tea and soft foods needs narrow occlusal contact areas and would find French's posteriors very well suited to her needs. Flat teeth which have too broad occlusal contact surfaces and little sluicing do not give the patient the feeling that he is penetrating his food. (From S. H. Payne: Selective occlusion. J. Pros. Den., *5*:301–304, 1955.)

interference has been eliminated are the choice. However, more care must be taken in setting up and balancing cusp teeth. We believe it is

definitely unwise to use unmodified interdigitated cusp teeth on a straight-line articulator, and feel that the existing confusion regarding the use of "flat" versus "cusp" tooth forms is attributable to that practice. The qualified prosthodontist who is a confirmed proponent of intercusped teeth does not use these teeth so carelessly, but sets them within the scope of a good articulator adjusted to three-dimensional jaw relations records. This alters the original tooth forms and gives smoothly working balanced occlusion with some freedom in centric occlusion. The man who chooses to work only from a centric relation record should not use intercusped teeth.

When interridge distance is great, as a result of rampant resorption and flatness of ridges, we use flat tooth forms to minimize thrust, allow for settling, and maintain maximal vertical and minimal horizontal forces. To prevent the patient's feeling that his teeth are not penetrating the food, adequate sluicing must be provided in these flat forms.

For orthognathous patients one can use either flat occlusal forms or nonintercusping cusp teeth. Because such patients have a wide range of mandibular movement, their jaws must not be locked in one position; here the reverse occlusal curve set-up works very well.

For prognathous patients we find a cusp tooth better for penetrating food with the open and close movement characteristic of their masticatory action, but in the occlusal scheme we allow for settling.

For the deviated mandible and very unusual jaw relations, the flat tooth forms are usually safest and provide the most stability to the bases.

One guide is to strive for a zero incisal guidance within the requirements of esthetics and not use cusps steeper than the angle of prominence of the ridges (see Fig. 4). Movement of the denture bases on the tissue produces much more resorption than static pressure. The bases tend to move anteroposteriorly if the intercuspation does not lie on the arc of closing of the mandible. This happens when centric occlusion is incorrect or if the dentures have settled and centric relation and centric occlusion no longer coincide. The bases will move laterally or anterolaterally in bare tooth play from the friction of the teeth on one another or from premature contacts.

The Try-in

It is important, therefore, to check the set-up very carefully at the try-in of the wax dentures. At this time the height of the occlusal plane should be observed approximately parallel to the ala-tragus plane and the lower posterior teeth should be slightly below the dorsum of the tongue. The second molar height will usually be about half or two-

thirds the height of the retromolar pad. The lower anterior teeth will be just inside the lower lip and will usually show at least 2 mm. The tongue should not be crowded posteriorly, which means we need to maintain ample width between the lower bicuspids on each side. This is the most common site of encroachment. The patient should walk around and talk so that the chosen vertical dimension can be verified. Enough time should be spent at the try-in to allow the patient to "get the feel" of the wax dentures in the mouth and to diminish the excessive flow of saliva. Then a careful check of tooth occlusion in centric relation and eccentric positions can be more easily accomplished.

Final Correction

Remounting, spot grinding and milling of the finished dentures is a very valuable procedure which corrects many otherwise unnoticed errors and reduces the postinsertion soreness and adjustment time. Correction can also be done in the mouth, using a central bearing point tracer. Adjust the bearing point so the teeth are just out of contact in centric relation. Gradually close the stud, recording and eliminating the interferences. Then polish the teeth with a rubber wheel. Having the patient chew milling paste is not as satisfactory because of the possible skidding of the bases. The use of articulating paper in the mouth to spot grind cannot accurately show the interferences because of the displacement of the bases and the thickness of the paper. A disclosing paste works better than articulating paper.

SUMMARY

The obvious and classic considerations in developing a posterior occlusal scheme can be found in a good textbook. We have in this paper attempted to emphasize some of these, but in addition to bring out other important facets of the problem which have not received adequate coverage. When our patients realize how they vary in size, shape, diet, physiology, pathology and adaptability they will look for and appreciate a finer denture service which only the dentist is able to give them.

3435 Main Street
Buffalo 14, N. Y.

[illegible]

Complete Denture Technique, Including Preparation and Conditioning

RALPH H. BOOS, D.D.S.

The preparation of the patient and the conditioning of oral tissue and the musculature are as important as the technical procedure for a complete denture service.

PREPARATION AND CONDITIONING

Preparation of the Patient

The preparation of the patient includes not only the economic and physiologic factors, but also the psychology involved in the denture service. Many times, the patient has definite concepts of a denture service which may affect the results obtained. The variation in patients may be from the completely cooperative, tolerant patient to the opposite who treats the denture as a foreign object and will not adjust to the limitations of a prosthetic service.

There may be a history of previous denture service which should be recorded and understood before starting a new service. A few planned questions regarding the denture history and the patient's viewpoint on prosthetics will provide leads concerning the involvement of psychosomatics. The patient may place the primary emphasis on esthetics, masticating efficiency, or some other phase, and will desire a greater degree of satisfaction in that one part of the service. There should be an understanding of these individual desires and attitudes, as sometimes they are not attainable, or there may be conditions involved which will reflect on the success of the denture service. As a result of this discussion, the operator will have a better understanding of his problems and the patient may better appreciate the scope and limitations of the service.

The preparation of the patient also includes the examination and study of the anatomic structures involved in the denture service, the

oral tissues, the musculature, and the temporomandibular joint. These anatomic structures may be affected by malfunction, pathology, allergy, diet, psychology, tissue displacement, and pressure. These conditions are often present previous to dentures and may be among the causes contributing to the need for the dentures. Malfunction is probably most frequently encountered and may be due to malocclusions, loss of teeth, and acquired conditions. The musculature and the temporomandibular joint, as well as masticatory functions, may be affected by malfunction. To proceed with the technical steps of denture construction without first correcting any abnormal conditions present may extend malfunction to the dentures and result in their limited use or failure.

Muscular Relaxation

The preparatory treatment for dentures involves all of the anatomic structures and should include consideration of all the factors which affect these structures. One of the most important of these structures is the musculature, which is a predominant factor in mandibular position, esthetics, and masticatory efficiency. A period of muscular conditioning previous to denture construction is needed to relieve tension, overcome acquired functional patterns and facilitate registration of the maxillo-mandibular relation. Conditioning of the muscles may be accomplished by an exercise which stretches all the muscles and lets them return to a rest position after each movement. This is the stretch-relax theory, which has proved to be an excellent treatment for the restoration of normal muscle function. The complete exercise for the head and neck area requires the patient to go through a series of movements of the mandible while holding the head in an upright position. The patient is seated in a normal upright posture in the dental chair with the back and head supported by the chair. The arms are on the arm rests, feet on the foot rest. The legs are not crossed, because crossing changes the skeletal position. With the patient in this relaxed, unstrained position, his attention is directed to the movements of the jaw which provide the stretch-relax procedure. First the patient opens wide for about one-half minute, then relaxes and lets the mandible come to rest position. No attempt is made to position the jaw. The teeth should not come into contact so there will not be any guidance by the existing occlusion. The lips may or may not be together, depending on the patient's normal relaxed facial contour. If dentures which he is presently wearing provide any interference, they should be removed. Next the patient moves the jaw to the right as far as possible in a slow, continuous stretch and then lets it drop

back again to rest position. The jaw should not be extremely open, just open enough to be free of any occlusion. The jaw then moves to the left and drops back to rest. Forward, back to rest, retruded as far as possible, and then to rest, and finally open again and back to rest. The mandible has been moved in every direction so all muscles attached between the mandible and the maxillae have been stretched and relaxed. The forward position and dropping back to rest, as well as opening wide and coming to rest, will often be most effective in bringing about a normal unstrained position.

This exercise may be given as a prescription, requiring the patient to follow the prescribed movements for 2 or 3 minutes four times a day. The times that would be most convenient would be in the morning after arising, around ten o'clock, around three o'clock and upon retiring. In severe cases pain may be present and should be reduced by sedation and hot packs. The patient should always be cognizant of maintaining a space between the teeth and avoiding biting habits. Whenever the patient finds himself biting or clenching his teeth, he should open and stretch the muscles to relieve tension.

The exercise is in no sense a method to develop muscle power. It is a procedure to relieve tension and learn relaxation. Exercises such as chewing gum should be avoided, as they bring the occlusion into stress and require muscle power. The exercise is helpful not only for conditioning the muscles, but also in facilitating movements required for jaw relation registrations.

It is my opinion that every case requires conditioning of supporting tissue and musculature even if all conditions appear normal. At the time the denture service is contracted, the patient should be put on the relaxation exercise. This will provide a minimum of a week to ten days of conditioning before jaw relations are registered. The longer the time, the better the advantage in obtaining and facilitating a normal registration.

Tissue Conditioning

Tissue displacement and pressure are present in varying degrees in every case in which a complete or partial denture base is on tissue which is movable and displaceable. The amount of change which takes place is dependent on the individual tolerance and habits, which may or may not cause abnormal pressure. Many times the history of a denture patient includes a succession of dentures constructed on displaced tissue. As each denture or reline is constructed, the old denture is removed and an impression is made of the tissues in their displaced condition. Under certain conditions, this may result in extreme dis-

placement, with varying degrees of recession plus possible nerve pressure evidenced by sensitive areas and a burning sensation. Observation will show the rugae and the incisive papilla greatly displaced in some cases. The incisive papilla is a protection to the anterior palatine foramen through which nerves and blood vessels pass. These factors may be treated by conditioning the tissue and by using nondisplacement procedures in the denture construction.

For tissue conditioning, the patient should refrain from wearing the previous dentures for an absolute minimum of 12 to 14 hours before the impression for the new denture or reline is obtained. Every patient is able to be without dentures and on a soft diet for at least over night. In cases of malfunction, inflamed areas, or burning sensations, the time should be extended to from 24 to 48 hours, or many days. The conditioning should continue until the appearance of the oral tissue is normal. The patient should be instructed to cleanse and stimulate the tissue by washing with cotton balls or a soft tooth brush using a normal saline solution or a mouth wash. The old denture should be out of the mouth as much as possible. An exercise to increase the blood circulation of the oral cavity has been suggested by Dr. Robert Sturgis and proves effective in restoring tissue to normal. This procedure involves taking a deep breath and closing the throat to stop exhaling while forcing down on the diaphragm. This will raise the blood column and increase relief and circulation in the denture areas. During the conditioning period, this may be done a number of times, and then again just previous to taking the final impression.

Allergic Conditions

Allergy to denture materials is always a possibility although, fortunately, the percentage of cases is extremely small in comparison to the number of dentures constructed. Many times affected areas have burning sensations attributed to an allergy when the actual cause is displacement of tissue and pressure on nerve endings, malfunction, or systemic conditions. In my opinion, the majority of so-called allergies are due to these other causes.

A true allergy may be considered when all of the tissue in contact with the denture material becomes irritated and inflamed. This irritation and inflammation should improve if the denture is removed, and when the denture is returned to position, the allergic condition should reappear. The function of the denture should be nearly normal, to eliminate malfunction as a possible cause. The vertical dimension and the centric relation should be reasonably satisfactory and the adaptation and size of the denture should be reasonably good. Inferior ma-

terials and improper processing may be the cause of the allergy. Some patients may be allergic to certain chemical components of the denture. The treatment for these true reactions is experimentation with other materials, such as a change from the copolymer methacrylate resins to the vinyl resins or to styrene resins. The most inert material possible would be a metal which is used as a surgical alloy.

Diet

The tone and the tolerance limits of tissue may be affected by the diet and systemic condition of the patient. Observation of substandard tissue and osseous structure should be investigated further by a general examination and medical contact. Often a discussion of the general diet and a report on a ten-day intake of food will indicate unusual habits. Natural foods, organic vitamins, and/or the therapeutic dosage of B and C vitamins are an aid in some cases. Extreme cases should be referred for medical or nutritional treatment.

Pathology

Pathology of oral structures should be carefully noted by clinical observation and roentgenography. Cases of leukoplakia, precancerous or cancerous lesions, or any questionable conditions should be examined by biopsy and/or referred for treatment. Roentgenography of edentulous cases will aid greatly in examination for anomalies, remaining teeth, roots of teeth, and conditions such as cysts or tumors.

PRINCIPLES OF PHYSIOLOGIC TECHNIQUE

A physiologic denture technique is based on several principles which aid in maintaining normal conditions. A nondisplacement type of impression is obtained because of the advantage provided. The tissue tolerance to biting force of different impression techniques was compared by processing denture bases on casts obtained from different impression techniques and then using a gnathodynamometer to register maximum biting force. The same patient had bases constructed on casts made from (1) a displacement impression, (2) a modified displacement impression, and (3) a nondisplacement impression. Each set of bases made from casts of different impression techniques was tested for maximum biting force. The results indicated approximately 20 per cent more tolerance to biting force with the nondisplacement technique bases over the displacement technique bases, and 10 per cent over the modified displacement bases. These percentages

could be varied by operator manipulation, but the nondisplacement technique indicated a definite advantage.

Jaw Relations

Physiologic rest position is used as a diagnostic reference position to establish vertical dimension including free-way space, centric relation, and a bilateral balance of jaw relations.

Rest position and maximum biting force are at the same position in vertical dimension. This provides a position of reference for establishing efficiency in mastication. In ideal cases, the bolus of food is placed on the posterior teeth, and the maximum force may be applied when the occlusal surfaces are about 2 mm. apart. This condition is present when there is a normal minimum free-way space of 3 mm. measured extraorally, nose to chin. If a greater free-way space is provided by closing 4 to 6 mm. from rest position, the bolus is compressed at a reduced muscle length and the force is less. The reduced force may be desired for patients with tender ridges.

The free-way space may be varied according to desired conditions of force and esthetics, but it must never be reduced to less than 2 mm. The patient must have a space between the teeth when he rests or there will be tension of muscles.

A physiologic centric relation may be obtained by closing from rest position in a normal unstrained hinge axis. In the majority of patients, about 65 per cent, this centric relation established by closing from rest position will coincide very closely with the centric relation indicated by the unstrained apex of the needle point tracing or by the unstrained posterior hinge axis.

In the remaining 35 per cent of patients, there is a tendency for the jaw relation to be forward of the posterior terminal position. This was indicated by the gnathodynamometer recording of maximum biting force in a free horizontal range. These registrations recorded as much as 20 pounds greater force in other positions than the posterior position. Some of these areas were as much as 7 mm. protrusive from the most retruded jaw position. For this reason, I have been using rest position as the reference relation for centric. Rest position is the neutral center of the masticatory musculature, and closing from that position includes a coordination of muscle function.

The use of the apex of the needle point tracing, or the posterior terminal hinge axis, as a centric relation would apparently be successful if good anterior and lateral balance of occlusion is provided. In this way, the patient would be able to masticate within the area included in the balance of occlusion. The patient might not use the cen-

tric relation provided for centric masticatory occlusion, but he would be free to move the mandible into any area he desired. Care should be taken to recognize the extent of movement which might be necessary, as it may be as much as 7 mm.

Bilateral balance of the mandible is obtained by eliminating any force in registration and avoiding any resistance which might tip the mandible laterally or up in the anterior or posterior ends. An unstrained position of the condyle in the temporomandibular joint follows as a natural sequence to unstrained registrations and occlusions.

DENTURE TECHNIQUE

With the preceding principles in mind, a complete technique for denture construction makes use of a preliminary impression, a spacer tray, and a nondisplacement final impression. Wax interocclusal records of centric and protrusive jaw relations, and a needle point tracing are made. These are followed by a trial set-up of teeth, plaster registrations of rest position, processing of the dentures, and recheck milling.

Preliminary Impression

The preliminary impression is obtained by selecting a metal edentulous tray, which is adapted to the mouth form and trimmed about 2 to 3 mm. short of the mucobuccal fold and attachments of the frenula. The postpalatal seal area is examined and classified as to throat form. (Class I is the flat extended throat form permitting a rather large area for the postpalatal seal. Class II is a modified drop of the tissue curtain posterior to the vibrating line between the hamular notches. Class III is an abrupt drop of the tissue curtain which limits the area of the postpalatal seal to a specific area.) The tray and impression should always extend past the final postpalatal seal area. As much area as possible, limited by the throat curtain, should be included in the impression. The tray is lined with a small roll of wax or modeling plastic around the border and across the palate for retention of the impression material and for stops.

Alginate is the material preferred for the preliminary impression because it does not displace tissue and it records fine detail. The disadvantages of alginate are in its border weakness and its questionable accuracy in bulk. Soft modeling plastic may be substituted for it.

The upper tray is seated with a finger in the vault of the tray and the patient is instructed to bring the lips and cheeks down over the tray with their own muscle power. The jaw is moved laterally to trim the

distobuccal angles around the tuberosities. The patient is instructed to suck on the finger that holds the tray in order to mold the postpalatal seal area. The impression is removed and poured in artificial stone immediately. Care must be taken to preserve the borders.

The lower tray, with the alginate in place, is seated by holding the tray with a finger on it in the molar region on each side. The labial and buccal borders are trimmed by having the patient bring the cheeks and lips up by their own muscle power. The tongue is wiped on the cheeks, over the vermilion of the lips, and then pressed against the thumb of the operator to trim the lingual border. These same movements are used in the final impressions. The impression is removed and poured immediately in artificial stone.

Spacer Trays

The outlines for the individual spacer trays are made with indelible pencil on the casts. On the upper, the tray line is approximately 3 mm. short of the mucobuccal fold. The postpalatal seal area should be examined in the mouth, and the flexion line of the soft tissue marked on the cast. This is usually in the area between the hamular notches and over the fovea palatinae, the two little depressions near the median line. The tray should extend past these landmarks approximately two millimeters. To construct the spacer tray, a thickness of baseplate wax is adapted to the cast without thinning it. The surface of the wax is coated with powder, and a second piece of wax is adapted over it and trimmed to the original outline. The second piece of wax is the pattern for the individual tray, which is made of metal or acrylic resin. An autopolymer resin or a good, properly processed acrylic resin may be used. Inferior acrylic resin, improperly processed, may warp and continually change its shape.

The lower tray is made in the same manner, using a spacer, and keeping it within the established border. Handles are placed on the trays for convenience in removal. Wax occlusion rims are placed over the posterior segments of the trays, leaving the anterior section open for tongue movement.

An all-wax occlusion rim is adapted to the lower cast to provide the wax interocclusal record of the maxillomandibular relation for mounting the needle point tracer.

The patient, previously instructed about conditioning the supporting tissue and musculature, will have had the old dentures out of the mouth for the required period of time at the next appointment. The trays are tried in the mouth and examined for any overextension. Any necessary trimming is completed, and holes are drilled in the palate

section and over the crest of the lower ridge with a No. 10 round bur. In the upper tray, two holes on each side lingual to the ridge and one in the palate are sufficient. On the lower tray, two holes are required on each side over the crest of the ridge. The occlusal surfaces of the wax occlusion rims are softened, and the trays are placed in the mouth to register a jaw relation. These wax occlusion rims are used only to hold the trays in place during the border molding.

A wax which softens at approximately 95° F., such as the Iowa wax, is used to record the borders at the mucobuccal fold and the postpalatal seal area. The wax is brought to its melting point in a vessel which will permit dipping the borders of the tray into it. Hot water is a good medium for heating the wax. The borders of the tray are dipped alternately in wax and in cold water. This method permits a rather fast building up of the wax borders. A small brush is used to fill in deficient areas of the wax borders of the tray. Approximately 3 mm. of wax are added to the entire border and the postpalatal seal areas. An effort is made to confine the wax to these areas. Excess wax on the tray is trimmed away with a knife. Usually, the lower tray is covered with wax, then the wax over the center of the ridge is removed, allowing the wax to remain on the border. Both trays are carried to the mouth and held in place long enough for the heat of the mouth to bring the wax to a moldable soft consistency. The patient then molds the borders by bringing the cheeks downward and sideways by muscle force, then sucking on the finger to shape the postpalatal seal. To form the vestibule buccal to the tuberosity, the mandible is moved from side to side. The tray may be removed and checked for overextension in any place. Any overextension is reduced, and the border molding is continued by adding wax as indicated and molding by muscle action until a definite mucobuccal fold and postpalatal seal are registered. The border thickness should not be overextended or over-thin, and the wax should not be carried into the ridge or palate areas. Any excess wax on the tray is cut away.

The lower impression procedures are very similar to those for the upper impression. The spacer tray is tried in position to see that there is no overextension. Soft impression wax is placed on the entire border, and the patient registers the limiting tissues in function. This is done by raising the cheeks and extending the tongue over the vermilion of the lip and the near surface of the cheeks. The tongue is forced against the thumb in the anterior region. The impression is removed and checked for overextensions and for accurate registration of the functional border. Additions and corrections may be made until an accurate functional border is registered. The retromolar pad should be registered in its normal position without displacement.

Final Impressions

The mouth is prepared for the final impression by washing off the tissue with cotton swabs soaked in saline solution or a mouth wash. The mucous membrane is then dried by gauze. The final impression is made in a zinc oxide and eugenol impression material or in a plaster composition type of material. These materials are used to record tissue detail, and to avoid any displacement of tissue on the ridge or palatal surfaces. Wax does not register tissue surface detail. The wax area may show through on the borders, but any area on the ridges or in the palate which shows through the impression requires a correction or a second impression. The cheek movements used in the functional trimming are used again for the final impression. The impression should record a functional border with slight displacement and accurate detail of the remaining denture area. No tray stops are used.

At this same appointment, the wax interocclusal record may be made. The occlusal surface of the occlusion rim made on the primary cast is softened, and a soft roll of wax is added on its occlusal surface. This is placed in the mouth, and the patient is directed to close until he has passed the rest position approximately 3 to 5 mm. An effort is made to have the mandible in a retruded position. This registration is used to mount the casts on an articulator, to facilitate the location of the needle point tracing apparatus. The tooth shade or shades and tooth mold are recorded with reference to the physical characteristics of the patient.

Before the next appointment, stabilized baseplates are made on the master cast. These may be constructed by adapting a baseplate with a spacer on the cast. The spacer is removed, and self-curing acrylic resin is used to obtain close adaptation to the master cast. In this way an accurate fit on the cast and in the mouth may be obtained. Attempts to transfer a baseplate from one cast to another would result in inaccuracy of fit in the mouth and loss of accuracy in seating the casts. The needle point tracing apparatus is mounted on the stabilized bases with a central bearing in the approximate center of the lower ridges.

Jaw Relations

Tracing Apparatus. Various types of tracers may be used, all of which have advantages under certain conditions. An extraoral needle and tracing plate, with a central bearing point centered in the lower

arch and the bearing plate in the upper arch, provides many advantages. The tracing may be readily observed, and the relative position of the mandible easily located on the tracing in various movements. By having the central bearing point attached to the lower occlusion rim, the approximate center of the area may be located and an equal bearing provided. On the upper baseplate, the bearing plate is in the palate between the ridges and this provides stability for the recording base.

An intraoral needle point tracing apparatus will provide more stability of the recording bases when the bearing point and tracer are located on the lower base and the bearing or tracing plate are on the upper base. The difficulty of having the bearing point or tracer located on the upper record base is that the bearing point may be located so far from the center of the lower base that in some of the movements the lower base may be unseated. For instance, in a protrusive moment, the upper bearing point may be so near the back edge of the lower bearing plate that the lower base would be tipped up in the anterior region.

In this technique, the extraoral tracer with a central bearing point on the lower base and a bearing plate on the upper base is used.

Vertical Dimension. At the next appointment, the maxillomandibular relation is established. First, the vertical dimension for the patient is considered. These considerations include the vertical dimension of the previous dentures, the esthetics, the condition of the patient's ridges, and the operator's judgment of what muscular efficiency to give the patient. The vertical dimension of the previous dentures should be registered for reference and comparison. The occlusal vertical dimension is established at a level 3 mm. closed from rest position to provide the ideal and maximum of efficiency. At this point, the patient will be able to masticate with maximum force, and the appearance may be ideal.

A measurement of the indicated occlusal vertical dimension is made and compared to that of the old dentures. If the change is greater than 5 to 6 mm., it is best to proceed cautiously, as considerable adjustment to the increased height would have to be made by the patient. Masticatory habits and adjustments by the lips and tongue may be difficult. If it is determined that the patient will adjust to the ideal vertical dimension gradually, it may be suggested that he have treatment dentures which would approach the ideal half-way. Then a year or so later the idea occlusal vertical dimension can be built into new dentures.

Consideration must be given to the ridges and the type of patient. If it appears best to reduce the amount of biting force, this may be

done by increasing the free-way space. If the occlusal vertical dimension is closed 5 to 6 mm. from rest position, there will be a considerable reduction in biting force. This may be an advantage for people who complain about tender ridges. As long as the vertical dimension registration permits a free-way space, and the patient is conscious of this space, the vertical dimension will not be open too far. The conditioning period which the patient went through with exercises will facilitate and registration of rest position, the amount of free-way space, and the needle point tracing.

Horizontal Extensions. After the vertical dimension has been determined, the needle point tracing is used with a tracing fluid on the bearing plate. The patient is instructed to move the mandible forward and back a number of times, then from back to each side until a definite (Gothic arch) tracing is recorded. This provides a record of the extensions of the horizontal movements of the mandible. Then tracing fluid is placed over the bearing plate again, except at the apex of the tracing. The needle used for making the tracing is secured with wax. The patient is then instructed to move the jaw from rest position to contact with the central bearing point in a tapping movement. This will mark the area of closure from rest position in a vertical function. The recording is then two dimensional, vertical and horizontal. These marks are examined to see whether or not they are in the area of the apex of the needle point tracing. If the marks are protrusive or lateral to the apex, there will be a large functional range, and the patient may not use the apex of the needle point tracing for mastication. Those cases having a large functional area should have posterior teeth with a mechanical, flat type of occlusal surface. There also should be a horizontal overlap of the anterior teeth equivalent to the distance from the apex of the tracing to the contact point of tapping.

Condyle Path. A registration of protrusive jaw position is recorded to adjust the condylar guidances on the articulator. This is done by having the patient protrude the mandible and recording the position with plaster of paris. The patient must make a straight forward protrusive movement to record the true condyle paths. A protrusive combined with a lateral movement records incorrect condyle paths. The centric relation is recorded by having the patient move the mandible so that the tracing needle is at the apex of the needle point tracing and making a registration in plaster. A face-bow is used for the orientation of the casts on the articulator.

Another method for registering the path of the condyles is by roentgenograph.

The laboratory procedure requires the selection of the articulator most familiar to the operator. The first cast is mounted in the position

indicated by the face-bow, or, if the articulator is designed on the spherical theory of occlusion, it is mounted according to the principles of the articulator. The second cast is mounted according to the plaster interocclusal record with the tracing needle at the apex of the needle point tracing. The condyle paths are adjusted to conform to the protrusive registration.

Tooth Arrangement

Too much importance cannot be placed on tooth selection and arrangement; every effort should be made to utilize the advantages of arrangement. Many times a patient will be satisfied with dentures because of their esthetic effect alone.

There are many principles which may be included in the set-up and balance of occlusion, such as the arcs presented, the Bennett movement, various types of adjustable instruments and other factors. Any one of these is important unto itself. At this time, primary consideration is given to other essentials. If the vertical dimension is normal, the height of the occlusal plane may be established at approximately the height of an arcuate line extending horizontally forward from a point about 2½ to 3 mm. below the top of the retromolar pads.

A more recently recognized essential in tooth arrangement is the establishment of a physiologic arch form. This is somewhat contrary to the rule of setting all of the teeth directly over the ridge. The teeth, including the bicuspid and anterior teeth, may be set in the normal position of natural teeth, regardless of the fact that they may be off of the ridge. This will establish a more normal function of the superficial layer of facial muscles. Esthetics and phonetics may be more normal for the patient. Extremes may not be tolerated, and it is necessary to use judgment in the application of this principle.

The Try-in

At the next appointment, the try-in of the wax dentures with the tooth set-up is made. Changes in esthetics are effected and a check is made of occlusion. This check includes the vertical dimension, the free-way space, and the balance of the occlusion. At this appointment, plaster interocclusal records of the position of the mandible at rest are obtained. With the trial set-up in place, the patient opens his mouth, and plaster is placed over the lower posterior teeth. The patient is instructed to bring the mandible to rest position for the record. A plaster which sets in 3 to 5 minutes is used, and a plaster syringe or a small spatula is employed to place the plaster on the teeth. At least

three registrations are made, and marked in pairs by the numbers 1, 2, and 3. Rest position is a reasonably constant position at the time of diagnosis, so the records should check with each other. Should the teeth penetrate the plaster and come into contact with their opponents, the vertical dimension of the occlusion is too great. In this circumstance, all the lower posterior teeth are removed and new plaster records are made. There must be no interference or contact of teeth through the plaster in this registration.

The plaster records and the trial tooth set-up are returned to the articulator which has the casts in the original mounting. One set of plaster blocks is placed in position to see if it checks with the original mounting. Each pair of plaster records is then checked. If they check with the original mounting, the needle point tracing, and the relation closing from rest position are at the same position. Under these circumstances, there should be a very satisfactory occlusion of the dentures. Should there be a difference between the plaster records and the centric mounting at the apex of the needle point tracing, the other plaster registrations should be examined. If the other registrations do not check with the apex, the lower cast should be remounted according to one pair of plaster registrations. The upper arm of the articulator is raised about 4 to 6 mm. above the horizontal position for this remounting. The other plaster registrations are then checked to this new mounting, and if they are the same, this rest position registration is accepted for determining the jaw relations.

The casts are now mounted in rest position. Free-way space is created by closing the articulator from this (rest) position. Three millimeters of free-way space is the minimum; more is used if conditions indicate the need for reducing the biting force. Closure occurs around the hinge axis from rest position. Centric relation is established after the vertical dimension for occlusion is determined. A bilateral balance of the mandible is maintained because the mounting was made at rest position, the neutral center of the musculature, and the closure on the articulator maintains the same length of the muscles. The teeth are arranged in balanced occlusion and then tried in the mouth. The occlusion in the various jaw positions is checked carefully.

Postpalatal Seal and Relief

The postpalatal seal area is located in the mouth between the pterygomaxillary notches, which are located posterior to the tuberosities. The line extends across the palate on the flexion line of the palate. It is usually close to the foveae palatinae, which are the two small depressions near the median line. The resiliency of the tissues is de-

termined with an egg-shaped burnisher or other blunt instrument. Usually, the lateral surfaces of the palate are displaceable, and the median line covering is relatively nondisplaceable. The postpalatal seal line is cut into the cast with a No. 10 round bur to about half the depths indicated by the probing with the blunt instrument. The anterior edge of the line is scraped out to a tapered depth. The formation of a postpalatal seal on the cast is a controlled displacement.

The relief to be provided over hard areas is determined by examination. Many cases do not require any relief when a nondisplacement technique is followed.

Regardless of the type of material used, it is a good procedure to recheck the occlusion after processing by returning the dentures to the articulator mounting before separating them from the casts.

Materials

Many beautiful materials are available for denture bases. The various pink materials are not only beautiful in color, but the physical properties are reasonably satisfactory. It is necessary to process the materials properly to bring out the physical properties which will best serve the requirements of dentures. The methyl methacrylate resins require extended processing at a critical temperature, plus a final temperature of 212° F. Cooling should be quite slow. Metal bases are a distinct advantage because of thermal conductivity, accuracy in form and fine detail reproduction. The tinting and characterizing of the plastic materials is one of the important advances in prosthetics. Patients can actually see this improvement, while technical advances are apparent only to the profession. The flexible or soft acrylic resins have a marked advantage when used as a lining material, particularly for lower dentures on sensitive ridges. After careful processing, the dentures are returned to the articulator and adjusted to balanced occlusion.

FINISHED DENTURE PRESENTATION

At the last appointment, the dentures are placed in the mouth and practically no adjustments are made. The steps included in the technique should produce a physiologic function which will be an advantage and comfort to the patient. Sometimes there are old habit patterns from the previous dentures which will reflect themselves in apparent errors of the new dentures, so extensive adjustments should not be made at the original insertion. The patient will eventually function much more efficiently with the new dentures. Within two to

three weeks after insertion, plaster registrations should be recorded at rest position, and the dentures should be remounted and the occlusion equilibrated as indicated.

The final instructions to the patient include the hygiene of dentures and the necessity of avoiding occlusion of the teeth as much as possible. The patient should understand that a space has been provided between the teeth when the jaw is at rest; this is the free-way space. Many denture wearers acquire the habit of clenching the teeth to gain a secure feeling. This continual pressure is damaging to the ridges. Most patients should leave at least one denture out of the mouth at night to avoid exerting pressure on the supporting tissues in this period. Many patients should continue the relaxation exercise to aid in the elimination of biting habits, and to relax the oral structures and the masticatory system.

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808 Nicollet Avenue
Minneapolis, Minnesota

The Management of the Trial Denture Base

SIDNEY I. SILVERMAN, D.D.S.*

The trial denture base, variously named base plate, shellac tray, wax rim, bite rim, occlusal rim, try-in, etc., is employed in all stages of denture prosthesis. It thus assumes a dominant role in the diagnostic and therapeutic procedures in both laboratory and clinical aspects of treatment. However, notwithstanding its major contribution to dental treatment, the trial denture base has for years been an underestimated and unappreciated procedure in complete denture prosthesis.

The title of this article was chosen deliberately to bring into sharper focus the contribution of the trial denture base to the practice of prosthesis. The term "management" has varied connotations; for this article it includes (1) diagnostic aspects of the trial base, (2) objectives of the employment of the trial base, (3) preparation of the denture base, (4) preparation of the wax or occlusal rims, (5) management of the trial base for determining occlusal records, and (6) arrangement of the teeth for the try-in.

Most of these aspects of management of the trial denture base represent the technical procedures in denture prosthesis; unfortunately, they have been only indifferently discussed in our current textbooks. Even more unfortunately, the diagnostic aspects of the trial denture base are completely neglected in our texts and publications. The trial denture base will be presented here as a major contributory factor in the clinical practice of denture prosthesis.

DIAGNOSTIC CONSIDERATIONS

The diagnostic aspects of the trial denture base have been inadequately developed by the profession. There are several reasons why it has been neglected as a diagnostic agent. One most significant reason is the tendency in the profession to relegate diagnostic con-

* Assistant Clinical Professor, Denture Prosthesis, New York University College of Dentistry and Assistant Clinical Professor, Physical Medicine and Rehabilitation, New York Medical College, Flower and Fifth Avenue Hospitals.

siderations only to the period of examination before treatment is started. Many practitioners very conscientiously make roentgenograms and study casts of the edentulous mouth, and feel they have fulfilled the requirements of an examination. Yet in truth the practitioner as he treats the patient learns more about the tissues and the patient's requirements after he starts treatment—for example, during the impression procedure, the occlusal records, or the try-ins—than he was able to during the so-called examination period. In effect each treatment session, each treatment procedure is in part diagnostic, for in treatment one must constantly re-evaluate both the clinical observations and the objectives of treatment. Each treatment experience gives new insight into tissue behavior and into the patient's expectations and his ability to adjust to dentures. Thus denture prosthesis is similar to treatment for any chronic disease in medicine and dentistry generally wherein the practitioner examines the tissues, evaluates the residual function and attempts to improve functions by supportive nutritional and pharmacologic therapy, by surgery, by physical agents, and by prosthesis. During all these stages of treatment, one must constantly re-evaluate the original diagnosis and when necessary modify a treatment plan. In prosthodontics the principal therapy is the prosthesis, the completed denture. However, just as in other phases of dentistry and medicine, one must constantly re-evaluate the diagnosis, the treatment, and ultimately the prognosis.

The trial denture base aids us in this constant and continuous re-evaluation of the diagnosis and the treatment. For example, when an apprehensive patient finds that he can retain the trial denture base for speaking, swallowing and easy breathing, he is reassured and is receptive to treatment in the recording procedures. On the other hand, a patient with xerostomia finds it difficult to retain an ill-fitting trial base without adequate saliva and is poorly conditioned for the trying experience of denture adjustment. Further, a provisional set-up in which the trial denture base is poorly adapted provides little validity to the correctness of the esthetic or phonetic considerations, whereas an appropriate trial base provides opportunity to evaluate the phonetics and esthetics and to make changes before the denture bases are permanently processed.

Too many times the practitioner learns for the first time that a patient is a severe "gagger" when the posterior palatal seal is first introduced to the patient's tissue at the time of insertion of the denture. It is also not uncommon for a practitioner to first note the unfavorable mandibular retrusion or protrusion or other unfavorable intermaxillary relationship at the time of the try-in of the temporary arrangement of the teeth. Only then, rather late in the treatment, does it become ap-

parent to him that there may be difficulties in esthetics or occlusal relationship. How much more desirable to know early in the examination and the first stages of treatment the problems one must encounter.

These examples are instances in the course of treatment which make diagnosis a continuous process in denture prosthesis. It may be said that diagnosis is not completed until the final adjustment, days after the insertion of the dentures.

A second major reason why the trial base has been neglected is that the profession has not fully appreciated the diagnostic potential of the trial plate, and has used it solely as a recording device and a vehicle for arranging the teeth. As such it has been accepted from the technician as an inadequately prepared trial base—so inadequate, it may be said, that it accounts for most of the difficulties the profession encounters in complete denture prosthesis. It is a vicious cycle wherein the dentist regards the fabrication of the trial base as a laboratory procedure which does not require great skill or judgment, and wherein the laboratory technician regards the trial denture base as something to be discarded without understanding the significance of what service the base renders in testing the impression, in determining denture equilibrium or stability during function, and in recording vertical dimension and centric relation. Therefore, between the dentist's indifference and the technician's lack of information the trial denture base is sorely abused.

The above diagnostic considerations which substantially influence the course of treatment depend largely upon an appropriately fabricated trial denture base (see Fig. 1A). There is a well defined body of information which provides the theoretic basis for what to expect of a base plate and how to use it most advantageously. Both the objectives in the trial base and the methods for preparing the base will be discussed here.

OBJECTIVES OF THE TRIAL DENTURE BASE

For almost two hundred years, the trial base has been used clinically essentially as a technical device for recording the face height, or the vertical dimension, and the centric relation. It has been presented as one of several technical or mechanical steps in the procedures of denture prosthesis. Today we have come to realize that the employment of the trial denture base, by the very nature of its use, is the most critical aspect of the whole procedure for the creation of dentures. It must embody all the anatomic characteristics of the oral cavity which are captured in the impression and subsequently transferred to the casts. Thus the base must cover all the tissues which will be the sup-

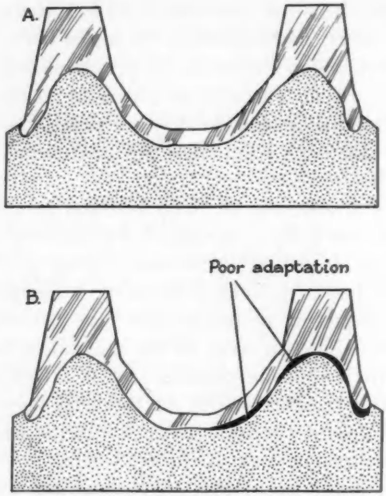

Fig. 1.

porting base and it must adjust to the displacement and other alteration of the tissues such as posterior palatal seal, maxillary torus, hypertrophic alveolar processes, etc. It must also be related to the functional activity of the oral structures, such as speech, respiration and deglutition, so that we may transfer the record of the maxillomandibular relationship in terms of the vertical dimension and the centric relation.

The primary objectives of the trial denture base in their order of sequence in the denture prosthesis procedures are as follows:

Impressions

When an impression has been completed it is too fragile and too susceptible to distortion to be placed back into the mouth for repeated or prolonged evaluation. However, a trial denture base carefully prepared may be placed in the mouth and the vestibular borders may deliberately be evaluated for extension and adaptation to muscle movement in open or closing movements, swallowing, speech, etc. The extent and depth of the posterior palatal seal may be determined with the aid of the trial base and, after preparation, may be incorporated into the trial base. The relief of either the mandibular or maxillary tori may be incorporated as well as the management of soft or hypertrophied tissues. All these considerations in the preparation of the impression and in the modification to the cast when in-

corporated into the construction of the trial base plate and placed in the oral cavity represent the completed denture base in terms of (*a*) coverage of denture-bearing area, (*b*) adaptation to the potential denture space in the vestibular and buccal fornix or border, (*c*) appropriate relief of excessively bony structures such as tori, (*d*) management of moveable hypertrophied tissue, and (*e*) compression and displacement of posterior palatal seal tissues.

In representing the completed denture form the trial base plates of both the maxilla and the mandible should thus exhibit the retention and stability we expect of the completed dentures for any given patient. Thus the clinical test for the impression procedure is provided by the trial denture base. If a patient cannot retain the trial denture bases in the oral cavity, the casts made from the impression, the impressions themselves, or the diagnostic considerations upon which the impression procedures were based are each or all suspect. If, however, a patient can talk, swallow, expectorate, speak and otherwise feel relatively comfortable with appropriately prepared trial bases, there is presumptive evidence that the impression and the bases are satisfactory.

Determination of Vertical Dimension

The determinations of the vertical dimensions of rest and of occlusion are the two procedures in denture prosthesis which require the greatest proficiency in technical skill and clinical judgment in denture prosthesis. The trial base is the key factor in this determination. When a proper base tray of a material of choice is secured, the next important phase in denture construction is preparation of the wax or occlusal rim. It must be recalled that the rims are oriented in space in three dimensions and therefore have the dimensions of height, width and depth, each of which must be observed and related clinically to (*a*) the denture base, (*b*) the bony and soft anatomic structures, and (*c*) the anthromorphologic planes of reference.

The orientation in space of the wax rims is described in clinical terms as follows:

1. *Arch form*—the contour of the labial and buccal and lingual surfaces of the wax rims.

2. *Arch position*—the positional relation of the wax rim to underlying alveolar ridge structures (it may be too labial or too lingual to the ridge form).

3. *Plane of orientation*—the height of the wax rim from the alveolar ridge and its parallelism to the ear-nose plane. This plane is essentially for determining the anterior plane of occlusion and for the con-

venience of transferring records to the articulator. It also provides the basis for the provisional posterior plane of occlusion.

The wax rim relates the arch form, position and height to its respective jaw, the mandible or maxilla. Its preparation must take into account the action of the facial and lingual musculature in the various functions and accommodate to the movements and the tension of these muscles and also to the subsequent alteration in the oral cavity spaces and tissue contours. The labiolingual width and contour and the inciso-alveolar height of the wax rim should represent as nearly as possible the morphology of the anticipated completed denture form and contour.

The wax rim represents not only the anticipated occlusal plane and contour but also reflects the patient's history of growth and development. When a patient has a history of severe malocclusion with considerable horizontal overjet of the incisor teeth, this phenomenon must be reflected in the contour of the wax rims. To reproduce this developmental relationship in the preparation of wax rims for a trial base one must be concerned at first only with the morphology and the arch form and position of each rim as it relates to its own alveolar structures. When the maxillary arch form has been prepared independently and the mandibular arch form has also been prepared independently, the two arch forms are related to each other. The adjustment related to the arches at this time is not one of arch form or width but rather one of height. The occlusal rims are reduced or increased in height so that the vertical dimension of rest and of occlusion may be observed.

Just as the validity of the impression procedure is checked by the denture base plate, so must the appropriateness of the wax rim be checked. The patient is required to wear in the mouth the trial base plate with properly contoured wax rim for a considerable period of time, perhaps 30 to 60 minutes continuously. The patient is required to swallow, expectorate, drink, change posture from sitting to walking, smoke, and speak with emotion and animation; in short, to perform all the functions except mastication with the trial base plate and wax rim in his mouth.

The clinician must observe the facial contours, the facility of expression, the degree of respiratory comfort and the general esthetic result which the patient exhibits with the trial denture base. If the patient appears to be comfortable and looks well after such an extended period the clinician may conclude that the total denture procedure to this point is satisfactory, i.e., that the impression and casts were satisfactory and that the vertical dimension and plane of orientation are satisfactory. One may now proceed to the next step.

Recording of Centric Relation

In the current practice of denture prosthesis the centric relation record is the most critical and the most intricate of all procedures. The trial plates and rims must capture the contour and position of the hard and soft structures of the oral cavity when they are adjusted to the position which the teeth and denture base will occupy when they are completed. With this information resident in the trial bases the clinician must then bring the rims together under minimal stress or force of closure and make an appropriate marking which will relate the opposing rims for transfer to the articulator device. With this service the trial base has not yet completed its recording responsibility. After having gone through the hazardous manipulations in the laboratory procedures of mounting the casts on the articulator it must be returned again to the mouth to check the correctness of (*a*) the record itself when it was made and (*b*) the laboratory procedures, where the hazards are manifold.

The centric relation record obtained with the trial base and wax rim carries considerable responsibility, for it is the basis upon which the teeth are arranged. It behooves the practitioner to observe carefully the correctness of the record both before and after mounting the casts on an articulator. The following is a simple clinical procedure for observing and checking the centric relation record:

The wax rims are cold trimmed until they have smooth, even occluding surfaces. The upper wax rim is marked with sharp grooves which are no more than 1 mm. in depth. The lower wax rim is softened several millimeters in depth and a mandibular closure is effected by placing the index fingers of both hands on the trial denture base flanges in the region of the bicuspids while the thumb is held gently under the border of the mandible. This placement of the fingers will generally stimulate the patient to automatically effect closure on the posterior occlusion. Placement of the fingers on the chin region generally stimulates the jaw reflex which places the mandible in protrusion.

When closure has been effected, the contacting surfaces are examined and any wax inclines more than 1 mm. in height are reduced with a sharp knife. The lower surface is then flamed and softened to a depth of 1 mm. and another closure is effected with minimal pressure or closing force.

The trial bases are removed from the mouth and occluded by hand. One must make sure that the posterior heels of the upper and lower trays are not in contact and that the wax surfaces are in stable and

simultaneous contact with well defined markings. The base trays are replaced in the mouth and firmly seated on their respective arches and the patient is directed to close gently in centric relation with the finger position as indicated above. The surface markings should coincide. The patient is then requested to close with more force and it should be noted again if the markings still coincide. Several repeated gentle closures should be effected, and if the initial points of closure with minimal pressure are identical with the final points of closure after exerting maximal closing force, it may be presumed that the record is correct. The casts may then be attached to the articulator. This procedure is valid for any articulator, from the simple hinge type to the more complex adjustable types.

If the surface markings do not coincide on minimal closing pressure, then either of two situations may result:

1. The lower rim may be forward of the upper rim and it would appear that we had placed the mandible in a more posterior position on the recorded closure. However, our most earnest efforts may not be able to bring the mandible further back again. In such instances the upper trial base probably slipped anteriorly from the alveolar ridge when the wax recording was achieved. An increase in closing pressure may permit the markings to coincide but if on opening again after placing the trial bases firmly on the alveolar ridges and closing with minimal pressure the markings do not coincide again, the record cannot be accepted and a new recording must be made.

2. The lower rim appears to be more posterior than the markings indicate. This situation simply means that the first recording was not sufficiently posterior. It may be that with increased closing force the markings coincide. This merely indicates that if the bases fit firmly to the tissues, the mandible simply moved forward bodily from the temporomandibular joint. Such a record is not acceptable and a new record must be made.

It is apparent that the centric record can only be obtained with a minimal closing force and that therefore the wax must be uniformly softened and the wax surfaces must have no grooves or ridges more than 1 mm. in depth or height. Conversely, an attempt to take a record with deep grooves or ridges with hard, unevenly softened wax or with more than minimal closing force generally leads to an incorrect centric record.

It is recommended that after the casts have been attached to the articulator the above-described check for centric record be repeated to eliminate the possibility that some errors have been introduced in the record because of debris or an inadequate mounting procedure.

To this point in the procedure of denture prosthesis the trial base

has continuously served a dual purpose: (1) to provide the technical or mechanical vehicle by which to bring the denture prosthesis close to accomplishment, and (2) to check, review and re-evaluate the accruing information and procedures which have been accomplished and whose successful achievement is necessary before the process can go forward to its logical end, the denture prosthesis. In review, to this point the trial plate has informed the clinician that (1) the impressions and bases are satisfactory, (2) the vertical dimension of occlusion is provisionally satisfactory, and (3) the provisional maxillo-mandibular relation has been transferred satisfactorily to the articulator.

Try-in of Tooth Arrangement

The final service the base tray renders is to provide a vehicle for the try-in of the arrangement of the teeth. It is in this step that the greatest faults appear in the trial base. Because of difficulty in arranging teeth, technicians frequently remove entire denture flanges from the labial arch areas and replace the firm shellac base with wax. This is not permissible, because the wax flanges are easily distorted and create problems in retention and stability of the trial denture base. Thus, when the patient should have the security of comfort and retention so that the try-in has validity, the denture base is not stable and provides little information about the esthetics and the occlusion of the try-in. By all means the trial base should be at least as firm as when the occlusal records were obtained.

The arrangement of teeth is fraught with serious consequences if left to technicians without appropriately prepared trial wax rims. Technicians do not understand the character of the hard and soft tissues and, when left to their own devices, regard the highest point on the alveolar arch as the center of a ridge and thus frequently arrange maxillary teeth too far palatally. The maxillary arch is thus constricted and the facial musculature is collapsed, the tongue has too little room and results are poor esthetics, poor speech and a host of other troubles. To avoid such difficulties the dentist must prepare a wax rim which has a proper labial arch form to place the facial musculature, and he must also create an incisal line to give the correct length of teeth. Once prepared, this form must be retained throughout all the recording procedures. The technician must place the labial surface of the maxillary teeth so as to coincide with the labial surface of the wax rim. The contour of the lower rim must also be respected and the labial surface of the lower anterior teeth should coincide with the labial surface of the wax rim. This may give rise to a normal horizontal and vertical

overjet, or it may be either a retruded or protruded mandibular relationship.

PREPARATION OF THE TRIAL DENTURE BASE

Treatment of the Cast

The first consideration in the preparation of a trial denture base is the treatment of the cast. There are several procedures which are absolutely necessary in this preparation. They are:

1. Management of all the artifacts caused by the mixing and pouring procedures of the casting stone. This includes the removal of bubbles of stone which result from the air trapped in the impression material; the filling of contour surfaces of the cast where air has been

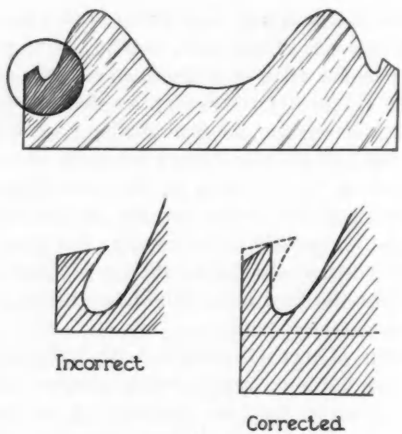

Fig. 2.

trapped in the casting stone while the cast was being poured; and the support of the walls and fragile structures of the cast, especially in the retromolar pad region of the mandibular cast.

2. The adjustment of artifacts due to the procedures for boxing the impressions. All undercut surfaces on the cast at the turn of the border reflections must be trimmed and altered if they interfere with the removal of the trial denture base from the cast (Fig. 2). The entire labial, buccal, and lingual reflection of the denture borders must be cleared for ease of removal of the trial base. However, the essential integrity of the border contour, depth, and width must be retained. The mandibular cast creates a particular problem in its distolingual border area. The lingual span in the mouth is occupied by the tongue

and the lingual alveolar reflection of mucous membrane which covers the tissues in the floor of the mouth. On the impression the space is occupied by the wax form or some other substance which is needed to permit the fabrication of the cast and also to provide strength to the cast. The cast must be carefully trimmed so the entire distolingual

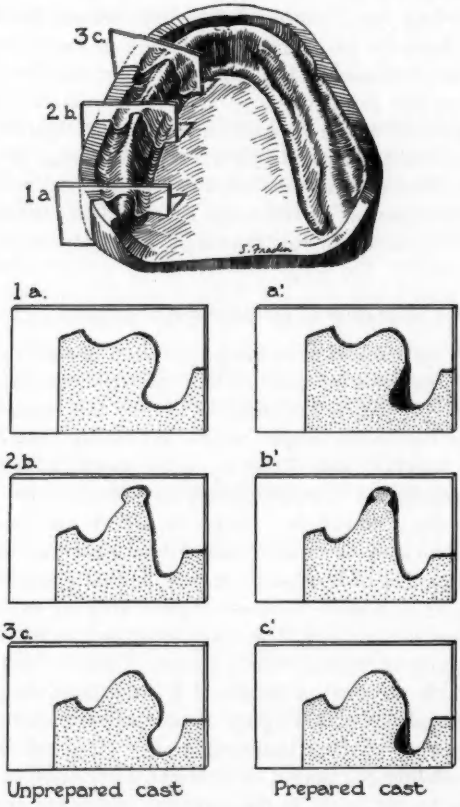

Fig. 3.

border is free of undercuts on the reflection side but does not lose its essential contour.

3. The treatment of the undercut areas on the denture-bearing surface. All undercut areas caused by the bony alveolar processes, bony excrescences or tori, or by the hard stone representation of soft tissue undercut surfaces, must be relieved by wax, clay, or some other plastic substance (Fig. 3). The relief of these areas must conform to

the relief of the undercuts caused by boxing and pouring procedures for the cast. It is apparent that all reliefs of the cast surfaces must be so related that the trial base will have a path of removal or separation from the cast surface which will not score, mar or break the surface of the cast, or warp or otherwise distort the trial denture base.

4. Modifications of the surface of the cast as part of treatment procedures, including modification of the cast surfaces for the posterior palatal seal where the cast surface is scraped, or the addition of metal foils which are cemented to the cast surface for relief of tori or sharp bony crests on the ridge surfaces. It is recommended that the trial base have incorporated in its contour all the anticipated adjustments to the soft and hard tissues so that the recording procedures for vertical dimension and centric relation and the try-in procedures of the provisional arrangement of the teeth can be done under the clinical conditions which the completed denture will have to meet.

Selection and Preparation of Denture Base Material

The second consideration in the preparation of the trial base is the choice and preparation of denture base material. Of the many materials and methods which are suitable for the fabrication of the trial base, the most commonly employed are the shellac base materials and the activated acrylic resins. They are both very satisfactory materials and the manufacturers provide appropriate instructions for their use which should be followed very carefully. There are, however, shortcomings with each of these materials. The shellac trays are malleable under a combination of heat and pressure, so that when shellac is used it should be as a double-thickness shellac tray or as two layers of single-thickness shellac tray. The trays must not be retained too long in the oral cavity or placed near a source of excess heat. The acrylic tray has unstable physical properties if it is not properly prepared and is prone to shrinkage and warpage if not properly stored. There are many modifications of these basic materials such as reinforcing shellac trays with modeling compound or wrought wire. Another modification introduced in recent years is the so-called stabilized tray wherein a corrective paste material is used to obtain a more accurately fitting trial base. These procedures are described adequately in the literature.

The important aspects in the clinical use of any base material are that it be sufficiently plastic for easy manipulation, that it be capable of reproducing the surfaces and contour of the cast, that it be sufficiently rigid to retain its form faithfully, that it be strong, durable and resistant to changes in temperature and pressures (to withstand mouth pressures and the necessary manipulation for recording and

articulator mounting procedures), and that it not be disagreeable in taste, odor or touch to the patient.

In the preparation of the trial base the material must be closely adapted to the cast surface, it must fill out all the contours in both depth and width of the borders, and it must be of smooth texture. In short, it must always be as close as possible in contour and texture to the completed processed denture base.

CONCLUSION

The trial denture base is a critical phase in denture prosthesis. Its diagnostic value is inestimable in that it permits us to anticipate the completed denture and thereby gives insight into the patient's difficulties, anxieties and capacity for adjustment to dentures. It further provides time and opportunity to study the esthetics more carefully and to evaluate more accurately some of the biomechanical problems inherent in the case. To accomplish this, the trial base must be carefully prepared to simulate the finished denture in contour, position and texture so that the occlusal records are obtained in the optimal clinical condition. The management of the trial denture base and wax rims must be a precise and carefully executed procedure if the completed dentures are to relate to the oral structures so that there is harmony between the prosthesis and the tissues as, collectively, they perform the functions of mastication, deglutition, speech and respiration.

80 Park Avenue
New York 16, New York

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Esthetics in Denture Construction

Roland D. Fisher, D.D.S.

We are told[1] that, as early as 1700 B.C., people made prosthetic appliances and bound artificial teeth in place by gold and silver wires, bands, and rivets, using human and ox teeth for replacements. The Phoenicians supply our earliest record of cosmetic consciousness and its influence upon prosthodontics.

In the intervening centuries we have very little evidence of much time or attention being devoted to restoration of the lost dentition. In fact, not until almost 3500 years later is there any record of the construction of a set of full dentures; these were made in America by Robert Woofendale.[2] Presumably the matter of retention and stabilization of denture bases in the mouth to insure function had presented such a problem that no serious consideration had been given to the cosmetic factor. This seems to have been the starting gun, however, and very soon after came the gold base and porcelain teeth which were now to have coloring within them rather than painted on them.[3]

In 1906, James Leon Williams began to work on improved anterior tooth forms.[4] In 1908 there was described a method of selecting sizes of artificial teeth by millimeter measurements,[5] and teeth with anatomic molds were produced a year later. Williams is credited with discovering the three typical tooth forms as far back as 1911. With the materials at hand we had made much progress in the direction of natural-appearing restorations; and had we not entered the intense mechanical era which gave birth to the airplane, the automobile, television, atomic energy, and a host of other remarkable discoveries, which in the author's opinion have distracted the profession, our esthetic advancement in prosthodontics would have been much greater than it has been.

In keeping with this mechanical age our profession became engrossed, shortly after the turn of the century, in the task of trying to construct a mechanical instrument capable of reproducing the movements of the human mandible, and many of these machines were designed.

With the advent of the articulator and the face bow, together with the Gothic arch tracing concept, we became absorbed in mechanistic theories—so much so, in fact, that for twenty-five or thirty years we neglected to develop the higher concepts of esthetics. We were deeply absorbed in the spherical theory, the triangulation theory and the tripod theory. We were busy thinking in terms of angles, triangles, and rectangles, of rotation centers of horizontal and vertical axes. We were busy drawing circles and concentric circles, arcs, and functional paths; but in spite of all our mechanical excellence the dentures we constructed were, with but few exceptions, even to the observing layman, false teeth. We had been so absorbed in mechanistic theories, so mesmerized by our age of automation, that we had neglected the higher concepts of esthetics.

Although much investigation was being done with posterior tooth forms as a result of the continued research with the articulator, it was not until about 1940 that some of our observing men began to realize that the anterior teeth were being neglected and that something more nearly resembling the natural tooth was very much needed and desired by the dentist.

Among these observing men was Milus M. House, who presented a masterful piece of research in 1939 under the title, "Form and Harmony in the Dental Art." About this time there were also produced teeth possessing far greater anatomic realism than had been seen before, tooth molds which were a very close approximation to natural teeth, and porcelain of greater hardness in a variety of desirable molds. Improved and varied methods in the manufacture of teeth gave us superior color blends. It thus became possible for the dentist to select the desired mold and shade of tooth from the products of a number of tooth manufacturers and, as a result, serve his patients more suitably and satisfactorily. It is true that we were beginning to benefit by the mechanical advances of the fabulous twentieth century. It is true that dentists were demanding an artificial tooth that more nearly resembled the natural tooth, and it is true that our contemporary dentists have been the stimulus of most of the research work that has resulted in the improved tooth of today. But somehow when the finished dentures have been placed in the mouth, in spite of the newly developed materials they still fall short of creating a desirable illusion of natural teeth. We are led, therefore, to take stock of our progress.

In 1952, John P. Frush, of San Marino, California, paid a visit to Switzerland and there spent considerable time with Wilhelm Zech, a noted sculptor whose father was a dentist. Dr. Frush was amazed at the examples of individualized dentures which the artist, Zech, had

created. Here, displayed in the mouths of patients, were distinctions in tooth form, shape, and coloring which definitely bespoke the varying stages of age and differences in personality as well as the sex of the individual patient.

Upon his return, Dr. Frush happened into my office one afternoon as I was attempting to rehabilitate the mouth of a beautiful young girl. She had lost all her teeth at the age of fifteen and had received conventional full dentures. Now at the age of twenty-three she had become aware of a decadent appearance in her face. A recent arrival from Iceland, struggling with a strange language and strange customs, trying to make new friends, she found her facial appearance to be an added obstacle.

With Dr. Frush's help we applied the principles of the sculptor, Zech, to her new dentures. The result was a transformation. It looked so real to the young lady that she declined to have it photographed, saying, "I am so pleased, I don't want anyone to know I have artificial teeth." Three months later she was married.

The complete freedom of this girl's smile was an inspiration to us all and the stimulus for intensive investigation and re-evaluation of the prevailing concepts of the time in denture esthetics, and it also contributed to the creation of the Swissedent Foundation devoted to esthetic research.

Young, in his writings,[6] has given a list of about twenty-one previous esthetic concepts, and no doubt there are many other men who have contributed ideas in this direction which have escaped publication.

In the course of this research it became evident that the word "esthetics" as applied to prosthetic dentistry was so broad in meaning that anything, in spite of its resemblance to false teeth, was considered acceptably representative of natural teeth, both by the dentist and by the patient, for evidently both were convinced that nothing more pleasingly natural could be accomplished.

DENTOGENICS

As a result of seeking a term really descriptive of a denture containing the sex, personality, and age attributes of the wearer so as to be eminently suitable in that it contributed to the wearer's charm, character, dignity, or beauty in a fully expressive smile, the word "dentogenic" was thoughtfully and carefully decided upon. The suffix *-genic* in the combined word dentogenic is meant to convey, in reference to prosthetic dentistry, exactly the same meaning that the suffix *-genic* conveys in the word photogenic. Precisely, according to Webster's dictionary, "photogenic" means "eminently suitable for produc-

tion or reproduction." Dentogenics, then, is the art, practice, and techniques used to achieve that esthetic goal in dentistry.

The ideas of Zech will not conclude research in this field, for it is elementary that as man increases his understanding in all fields of investigation, revelations continue to occur; and while we look with the same eyes, we *see* with progressive minds. Consequently, Zech's accomplishments are but a hopeful contribution toward the stimulus which must take place in dentistry if we are to advance from our present-day concepts which to us seem to be sadly in need of reevaluation.

Zech's ideas were evolved from his training in observing human anatomy in the living model. Then, observing his father's denture restorations, he was struck by their failure to harmonize with nature, by their obvious falseness and conspicuous unreality, and by their complete disharmony with their environment, that is, with the personality as a whole.

In forsaking the effects of our present-day mechanistic age thinking, in putting away the tendency of many dentists to make a mechanical instrument the guiding factor in ultimate tooth form and position, in setting aside the geometric interpretation of the human face as the dominant theme for tooth selection, and in substituting for these abstractions the same basis that has existed for all art since the earliest record, namely, the human form in toto, Zech presented us with a living, pulsating and inexhaustible basis as a guide to the individual expression of the human personality in prosthodontics. In retrospect it seems almost impossible that the profession should have wandered so far from the obvious and the direct and the immediately available in search of a standard for the selection and positioning of the teeth in the denture; the answer apparently lies in the mesmeric appeal of the mechanistic impulse. Since the earliest of eras all sculptors have found their greatest inspiration in interpreting the human form, and it seems to be only the signs of the times that would tempt us to look to inanimate and geometric concepts for the answer to the intriguing problem of forming and positioning the substitute for lost dentition.

Obviously we utilize the approach of the artist when we analyze the patient first as to sex, that is, male or female; then as to personality, vigorous or delicate; and then as to age, young, middle-aged, or old. As artists in dentistry—and such we are certainly called upon to be—we are confronted with the responsibility of restoring not only function but also form, and it is here that as a result of the mechanistic age we could be influenced to overemphasize function and subordinate to a state of negligible concern the cosmetic factor.

The author, in a combined research effort with Dr. Frush, has con-

tinued to seek reasonable solutions to some of these esthetic problems. We have attempted to give, in a series of articles published in the Journal of Prosthetic Dentistry,[7] a more detailed interpretation than this article will permit. Assuming an approach to a patient similar to that of the sculptor to a model, we begin to consider the ideal characteristics of femininity and masculinity.

THE SEX FACTOR

Webster gives one definition of *masculine* as "having the qualities of a man; virile, robust; mannish, strong, or vigorous"; while of *feminine* the same dictionary says "effeminate; tender and soft." The artistic concept of the feminine form, as revealed in sculpture and paintings, is characterized by soft, flowing lines which may be incorporated effectively in the form of porcelain anterior teeth. The suggestion of tenderness and softness is thus made possible in the carved porcelain tooth in the same manner in which the sculptor expresses femininity in his inanimate stone. Conversely, the personification of the vigorous and robust masculine form, as seen in artistic interpretations of masculine virility and strength, can be expressed in the carvings of the male anterior tooth form.

THE PERSONALITY FACTOR

As a starting point in the personality analysis of the patient, then, we have learned to anticipate the opportunity to suggest the ideal qualities of the sexes in tooth form. Of course, it is possible to observe variable degrees of softness, tenderness, and delicacy in women as well as wide contrasts in the virility and ruggedness of men. It therefore becomes necessary to have a second basic factor in this analysis, which we shall call the "personality factor." Imagine, if you will, a twelve inch ruler marked off into sixty-fourths of an inch. Call one end of the ruler "Vigorous" and the other end, "Delicate." Every sixty-fourth of an inch would represent a divergence away from the middle toward one or the other extremity. Of course, nature provides an infinitely greater number of variations of objective personalities than can be suggested by sixty-fourth inch divisions on a one foot ruler.

Generally speaking, it is safe to say that men are more vigorous than women, for vigor is a characteristic of masculinity; tenderness and softness, which express femininity, are more suitable to women, although they are not always as highly developed as the idealist might desire.

These qualities of vigor or delicacy may be expressed in the or-

ganized dental composition by first selecting an appropriate tooth form to suggest the correct sex quality and then by the subtle positioning of the tooth in the arch.

In Figure 1 we see a dentogenic dental composition suggesting masculine vigor and ruggedness. The tooth form itself is sculptored

Fig. 1.

Fig. 2.

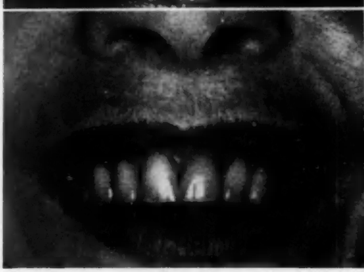

Fig. 3.

Fig. 4.

Fig. 1. Masculinity, vigor and age are here depicted in tooth sculpturing and gum carving; however, cuspid inclination and the smiling line keeps the mouth pleasingly dignified.

Fig. 2. Youthful femininity here shown is enhanced by the careful use of the diastema between the right lateral and central incisors.

Fig. 3. Use of the flat plane concept of dental composition creates disharmony with the smiling mouth and contributes to the "denture look."

Fig. 4. The conventional composition here shown is two dimensional. Meaningful porcelain sculpturing and artistic spacing, as in Figure 1, compel the illusion of the third dimension.

forcefully; the anatomic carving suggests boniness and hardness. The central incisors are placed with the mesial surfaces set in lingually, while the distal aspect is brought anteriorly or forward so as to display the sculptoring of this surface. The lateral incisors are placed at varying long axes to the central incisors and also to each other, and the desired degree of vigor is obtained by rotating the laterals until the mesial surfaces of either one or both of these teeth are dominated by the central incisors. The canines are artistically of great importance,

for they are the gateway to the buccal corridor or the area between the buccal surfaces of the posterior teeth and the oral surface of the cheek. Placing the canines in at the tips tends to open this area to vision and avoids a toothy or anthropoidal suggestion. This becomes a very useful factor when arranging the dental composition, for by moving the tips of the canines out or in, variable degrees of vigor or delicacy may be suggested.

It is not desirable to limit the application of one's concept of denture esthetics to the six anterior teeth, for the bicuspid teeth and the molars are frequently of much importance when the mouth is viewed from a frontal position; therefore, these teeth must be considered as part of the esthetic arch. In Figure 1 note the variation of the long axes of the bicuspid teeth to avoid a monotonous and conventional appearance and to retain the desired quality of vigor in this particular composition.

If the problem should be to effect a dental composition which would suggest delicacy rather than vigor, we should begin by thinking of the general characteristics of a physical personality expressing frailty, weakness, or infirmity. While many women would resent, and rightfully so, the implication that women are frail or weak, yet to idealize them as being tender, soft, and delicate is only to exercise an artistic sense in a desire to express a spiritual quality even more than a physical one. Therefore, in Figure 2 the soft, flowing lines of the female figure are transposed to the form of these teeth. The sculpturing is softer. The anatomic carving is less pronounced, and the surface is smoother. The central incisors are full labial face to the front. The lateral incisors are rounded with the mesial surfaces now exposed to view, although the long axes should be varied ever so slightly to avoid the suggestion of mechanical monotony. In this case the canines are in at the tips to expose the buccal corridor and create a civilizing effect. In every case it is recommended that the canines be so turned that only the mesial aspect of the tooth is visible when viewed from directly in front of the patient. In a softer version of the dental composition it is quite appropriate to keep the buccal aspect of the bicuspids and molars more nearly in harmony with the labial incline of the canines—reducing in this manner the sense of action or virility in keeping with the objective personality of the patient.

THE AGE FACTOR

The task of the prosthodonist in his esthetic efforts is somewhat complicated in that he is required to compose dental compositions for patients of all ages. However, it is safe to say—inasmuch as edentation

is principally a result of advancing age—that most of his patients will fall in the category of middle age or older. We are led then, as we further consider the personality analysis, to a third basic factor, namely the consideration and interpretation of age.

If we should accept the Biblical declaration of man's years as "three score and ten" and the aim of the dental profession to see that every person arrives at that age with a full complement of natural teeth, we are faced with the facts that although a few people do attain this consummation, most of them do not. It has been within the experience of most dentists to see one or more patients completely edentulous while still in their teens. These persons, then, while chronologically young, are, dentally speaking, physiologically old; hence it becomes the artistic task to restore all edentulous patients to an appropriate chronologic dental state.

Strangely enough, while the great majority of our patients are in advanced age, practically all artificial teeth being manufactured today look as though all denture patients were expected to be teen-agers; and because of technical difficulties as well as the lack of understanding of the importance of this factor, most of the teeth are used without alteration, and we find patients from eighteen to eighty looking physically decades apart, but dentally all like high school seniors.

The passing of years leaves marked effects upon the body, and even those most favored in having retained their natural teeth to advanced age will display some dental evidences of the vicissitudes of time.

It is generally accepted in dental literature that the average person of eighteen years has already lost two teeth, at nineteen, three teeth, and so on until at thirty the average person has lost a total of eight teeth; thus it may be expected that at this age some drifting of the remaining teeth has occurred. Most people have had occasion to have fillings placed in their teeth by the age of twenty, some of these in the incisors and canines; as a result, some discoloration of these teeth is usually in evidence. In advancing years the translucent incisal edges are worn away and pathologic involvements of the bone cause further displacement of the remaining teeth. Trauma and common habits—the use of tobacco, coffee, and tea—all make their contribution to the general effect which we identify as advancing age.

When a dental composition is being organized in which we desire to create the pleasing illusion of natural teeth, these dental evidences of age must be considered from an artistically acceptable viewpoint.

DETAILS IN EXPRESSION OF THE DENTOGENIC CONCEPT

Natural teeth that are pleasing in appearance seem to follow what we refer to as a "smiling line." That is, the incisal edges of the upper

incisor teeth curve to form an arch with its lowest point located at the central incisors; the laterals are shorter and the cuspids still shorter. When the mouth is smiling, the curve of the smiling line of the upper teeth parallels or is concentric with the upper border of the lower lip.

The anterior tooth composition in the conventional denture is usually set with all of the six anterior teeth on a flat plane and very nearly the same length. This meets the curve of the lower lip in disharmony and creates the "denture look" that is readily detected even by the average layman. Figure 2 demonstrates the "smiling line" in a full upper dentogenic restoration, while in Figure 3 we see a conventional denture.

In the past the subject of esthetics has usually rested its case upon the consideration of the tooth and its position; but the sculptor, Zech, with the critical eye of the artist, was able to observe that the environment of the tooth, the denture base or matrix, was equally important in achieving the ultimate of a natural appearance.

In the last few years intensive research has confirmed Zech's theories of the importance of the contouring of the interdental papillae and the gingival crest in order to complete the illusion of the natural tooth as it is found in its native environment in people of all ages. It was discovered that the dentist and the dental technician had carried certain customs with them from the days of the rubber denture base, and one of these customs is to hide the interdental papillae as they did in the old days by removing them from the interdental area. In so doing, the importance of the interdental papillae was inadvertently removed from our conscious esthetic efforts in the general course of laboratory procedure. Nearly all conventional dentures appear to have a common interdental papilla design, as shown in Figure 4. This design not only contributes to the mechanical denture look but also creates crevices and pockets for food impaction, plaque formation and bacterial growth. The matrix of the artificial tooth should be meaningful: it should attempt to achieve the appearance of youth, middle age, or old age, according to the ageing of the other tissues of the body. The interdental papillae should be full and convex, and thoughtfully designed in such a manner as not only to make the denture as self cleansing as possible but also to achieve reality. Comparing Figure 1 with Figure 4 will illustrate the contrasting treatment of the papillae.

In the dentogenic concept, since the importance of the tooth, its position, and its matrix as used in the artificial denture are intimately integrated with the sex, personality and age of the patient, any appraisal of the success of the organized dental composition would depend upon its being viewed in the mouth of the person for whom it was made. This is the only successful test. Obviously the denture made for the young, teen-age girl—charmingly delicate as it would be

—could not possibly be acceptable in the mouth of the aged and infirm woman; neither would a restoration suitable in either of these mouths be considered a dentogenic restoration if transferred to a matrix for a man.

It is the purpose of those who have labored diligently and long in the pursuit of a more workable basic principle in esthetics to encourage all of those whose tasks take them into the field of prosthodontics to consider the opportunity to lift the patient out of the category of a geometric figure and restore to him his true quality of a living and breathing man or woman, with an individual personality and either the dignity of his years or the freshness of his youth.

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603 South Central Avenue
Glendale, California

The Appearance Phase of Denture Construction

M. M. DeVan, D.D.S.

The word "appearance" is employed in the title of this presentation because it denotes our over-all objective better than the words "esthetics" or "cosmetics." These terms conjure up in one's mind the thought of beauty and beautifying. This may be in contrast with a phase of our aim which is merely to create a bland dental composition —one that is neither above nor below the cosmetic average. Our strategy may be to make the teeth neither an adornment nor a detriment to the countenance, thus causing the onlooker to by-pass them for other features of the face.

Before the dental composition is begun, we must decide what role the mouth is to play in the over-all appearance of the face. Is it to dominate or is it to play a role secondary to the other features, especially the eyes? Dominance is attained primarily through prominence. Prominence depends on the factors of position, proportion, pitch and brightness.

Dental compositions are not interchangeable. They must fit the face as uniquely as impressions fit the mouth. The rule is, the younger the patient the more vivacious the composition; that is, the greater its dominance. Dominance results in making the mouth the focal point of the face. This confers to youth a mouth attractive to the opposite sex; it injects the element of voluptuousness to the lips. This dominance of the mouth generally recedes as a person gets older, and if age does not cause a recession of the mouth the person looks strange, the strangeness resulting from the presence of form without the probability of function.

The appearance phase is no exception to the pattern prevailing in other phases of denture construction, that is, there are many diverging viewpoints. And while we may reasonably hope to be able to resolve our differences of opinion about impression taking, and about positioning, proportioning, pitching and forming posterior teeth and other related factors, it is hopeless to believe we can agree in the phase under discussion. This is because we react with feeling and not with

thought to the appearance of teeth, and our feelings depend on our background, our mood, our experiences.

It would probably be as fruitless to argue among ourselves as to what is appropriate and pleasing as it would be to argue with our patients about the appearance of denture teeth. There are two schools of endeavor relative to organizing of the dental composition. The first school seeks to construct dentures that are beautiful. The second school strives after naturalness. There are many camps in between these two extremes.

Members of the "cosmetic" group support their viewpoints as follows: "Why make them natural," they ask, "is there anything quite natural about the average urban and suburban man today? Without the use of a safety razor plus the service of the barber, the mature male would be so full of facial fur that much of his face would be concealed." They advance still more convincing arguments about the mature and aging female. "What is natural about her," they inquire, "is the color of her lips natural, the surface texture and color of her facial skin?" They continue: "How about the color and contour of her eyebrows and eyelashes—are they natural? Or the color, sheen and arrangement of her hair? Need we go further," they ask, "to justify our contention that artificial teeth should be made beautiful rather than natural?"

To all this, members of the "natural" group reply, "All that you have said is true, and yet it is also true that this facial artifice fools very few and offends many. The trouble with all these attempts to hide the 'plain Jane' or the aging process," they continue, "is that they seldom, if ever, succeed; there always remain tell-tale signs about the face and neck. These unsuccessful endeavors to conceal plainness of face or aging," they add, "often make the human face a farce—a farce that provokes laughter or disgust, depending on whether one enjoys folly in others or is annoyed by it."

The "natural" school advances the following thoughts: Cosmetics are used for three purposes—(1) to accentuate beauty, (2) to hide defects, and (3) to conceal the aging process. The "natural" school does not object to the use of cosmetics to hide hideous defects. It is even tolerant of their moderate use to accentuate beauty; its main objection is to the use of cosmetics in attempts to conceal effects of aging.

We cannot maintain the bloom of youth; changes in the color and texture of the facial features, especially of the skin, cannot be avoided or successfully concealed. Teeth also age and when replaced they should be made to match the chronologic status of the facial features. Teeth alter in position, in proportion, in color, in tilt, in surface tex-

ture, in surface detail. All this effects the over-all appearance of the dental composition, and not always adversely when we consider the appearance of the face as a whole. If the teeth did not change, they would be in sharp contrast with the features of the face that do change. If the features of the face look as though they have been around a long time, the teeth should also appear as though they too have been subjected to the vicissitudes of life. Teeth should appear as though they have been lived with like the rest of the face. This school maintains that to do otherwise is actually to destroy the peculiar charm that is unique with the aging face, especially the expression of the eyes.

This school emphasizes that an old face tends to look older in the presence of an artifice devised to make it appear younger, such as a conspicuous toupee, or bright and perfect teeth. They argue that when teeth of high brilliance are framed by facial skin of low brilliance, the effect is to cause the skin to appear even more shallow and lustreless. Perfection in the dental composition of any of these factors should be matched by perfection in the other facial features. To do otherwise, they continue, is to risk adverse psychological reactions—the onlooker may conclude that because the teeth look artificial, the entire expression may be put on.

Where does the author stand in this divergence of opinion? For years he has been in the natural camp. I can recall a case in which the reproduction through staining was so unesthetically natural that it was impossible to detect a substitute denture. But the patient was displeased, and complained that his friends would ask, "Why don't you get your teeth fixed?"

My present practice is to match the substitute denture cosmetically with the face, natural or otherwise. If the features of the face are comely, the dental factors employed are comely. This comeliness may be partly due to cosmetics. I attempt to match the appearance of the dental composition with the appearance of the face, cosmeticized or natural. If the make-up is heavy the teeth are also heavily made up, i.e., made younger and prettier. If the face is essentially plain we do not make the teeth fancy. Cosmetic harmony of the facial features and the dental composition is the goal. We deviate from the general rule only when the patient insists on having beautiful teeth.

Let us now discuss in detail the factors responsible for the muco-dental composition. (The term "muco-dental" is employed because we plan to substitute for the lost mucosa with its underlying bone, as well as for the lost teeth. Attempts to replace the loss with teeth alone, as is done with fixed bridge work, will leave much to be desired cosmetically, for butting the teeth against the gum may necessitate

malpositioning, malproportioning, malpitching and malforming the substitute teeth. That is, teeth are set further up than the esthetic ideal, teeth are generally made longer than face length will dictate, and they are pitched too much to the labial. Teeth are also formed in the square to block out unsightly interproximal spaces. In addition to the above undesirable tooth factors, the upper lip invariably appears to lack the desirable degree of medial fullness.)

FLANGE FACTORS

The flange factors are four in number: height, thickness, color, and surface detail and texture.

Height of Flange

The height of the labial flange is determined by the requirements of a pleasing appearance of the lips in relationship to the nose and the cheeks. The appearance phase may require a shorter flange than the retentive phase may dictate and we should be willing to forego the added retention that may result when the labial flange is carried to the so-called functional path of the border muscles.

It is not within the scope of this paper to discuss the factors responsible for the stability of dentures, yet one important question may arise in the reader's mind: how can one get sufficient retention without a border seal secured through flange extension to the functional path of the border tissues? The answer is, one cannot unless the denture is fairly well stabilized, which makes it unnecessary to have the maximal retention possible in a given case.

Thickness of Flange

The thickness of the labial flange is fashioned so as to give the base of the nose and lips a pleasing contour. A pleasing nose and lip contour may require of one case a low, thin flange; of another, a high, thick flange; of a third, the combination of low and thin on one side, high and thick on the other side.

Color of the Labial Flange

Thanks to Earl Pound and others, the labial flange may now be colored to minutely resemble the natural mucosa. We no longer have to avoid the showing of the "gums" by using unnaturally long teeth.

Surface Detail and Texture

The carving of the labial surface and its surface texture are probably as important as color in the over-all appearance. Earl Pound recommends prominent gingival bands resembling cuticles. When the teeth are festooned with these gingival bands, high here and low there, depending on the way teeth are pitched, the illusion is indeed that of living mucosa.

TOOTH FACTORS

The tooth factors are six in number: position, proportion, pitch, brightness, outline form, and surface detail and texture. These factors

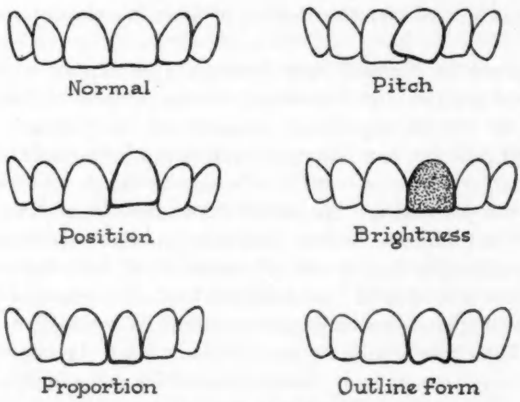

Fig. 1. Factors affecting dental esthetics.

are illustrated in Figure 1, except for surface detail and texture, which is difficult to show in a drawing.

Position

The position of the teeth in relation to the moving frame of the lips is by far the most important factor in their general appearance. The position of the maxillary anterior teeth in three planes determines the contour of the upper lip in rest position, in speech and in laughter. One can readily note the extreme importance of position by watching performers on television. It is difficult, if not impossible, to detect the size, inclination or form of the teeth; all one sees is brightness and tooth position.

It has always appeared to me strange that the form of teeth has had

so much emphasis and position nearly none. Dr. Sherman, of Ohio State University, has said, "You don't know *what* a thing is until you know *where* it is." The factor of "whereness," or position, has to be settled in one's mind before "whatness," or size and form, is considered. Many dental compositions displease because teeth suitable as to size and form are placed too far up or down, too far forward or backward, too far to the left or right in relation to the lips, nose and other facial features.

Position is decided when denture models (bite blocks) are contoured. Thus, the most important factor in appearance is assured or jeopardized before the teeth are selected. The following considerations influence the positioning of maxillary anterior teeth: (1) contour of the lips in postural rest position; (2) the degree of tooth visibility during speech; and (3) the degree of visibility during smiling and laughing.

Lip Contour in Postural Rest Position. The contour of the lips in postural rest position (as determined by the position of the teeth and flange) is of utmost importance, because we are probably observed most in rest position. Note that no mention has been made of positioning the maxillary anterior teeth in reference to the alveolar ridge. With our plan, the patients are instructed not to use the anterior teeth for incision. Non-traumatic incisive function would necessitate compromises in positioning that would adversely effect esthetics and phonetics. Patients are advised that anterior teeth are placed where they look the best; that front teeth are essentially a front—they only look the part. Their use in incising food is likely not to be conservative of the underlying osseous base. Incision should be manual with the aid of a knife and fork. We, as mouth physicians, have a perfect right to prescribe what patients may or may not do with an oral prosthesis, and it has been my experience that when patients are told that their chances of conserving the remaining alveolar bone are better when they avoid incision, they will generally cooperate.

George Cox, of Wilmington, Delaware, has suggested instructing the patient to count up to 25 to note the degree of tooth visibility during conversation. I have found this good counsel, especially when the word "cheese" is interjected at the end of each numeral. The word "cheese" not only reveals the teeth, it also provokes merriment and laughter.

Mood and the Muco-dental Composition. This brings up the question of the mood of the prosthodontist while organizing the mucodental composition. He should be in a gay mood where light-heartedness and mirth prevail. Humorous stories appropriate to the patient should be forthcoming from our lips. ("Appropriate to the patient" is

an important point to keep in mind, especially if one has been to a dental meeting the night before. A safe rule to follow is, never tell a story to a woman that another woman has not told you; even then one can get into trouble.) To note the degree of tooth and flange visibility, it is not enough to instruct a patient to smile, one must provide provocation. Laughter will not only help to locate the high lip line but it will also aid in relaxing the facial muscles, which is essential in registering jaw relations.

Festooning. In those cases where the curtain of the upper lip rises high above appropriately placed and proportioned central incisors, Earl Pound's technique of festooning and tinting the labial flange is indeed an appearance aid. We have found his bold and prominent gingival bands not only a pleasing transition from tooth to mucosa (because of the retention of a salivary film) but also a deterrent to excessive vertical lip movement. Pound's prominent gingival carvings act as a welcomed curb to lip movement vertically. The mat-like surface texture of his labial flange also tends to limit movement. Because of Pound's contributions in esthetics, it is no longer necessary to malposition anterior teeth solely for the purpose of avoiding the showing of mucosa.

Effect of SPA Factors on Position. Under the term "dentogenics," Frush and Fisher have advanced a useful concept in organizing the dental composition. It is based on *sex, personality* and *age* of the patient, which they call the "SPA factors." They state that when dentogenics is applied to denture construction it will be possible to tell, with only the dentures in hand, the sex, personality and age of the person for whom they were constructed.

How do the SPA factors (sex, personality and age) affect position?

Sex. A man generally requires a greater degree of prominence than a woman. More important than prominence is the so-called incisal sky-line of the teeth. Men have a straighter incisal sky-line than women. Women look more attractive with a curvaceous sky-line, one that is concentric with the curvature of the lower lip during smiling. Roland Fisher first caused me to be aware of this factor in the dental composition, and there is no doubt that my female compositions have improved in attractiveness owing to my awareness of this relationship between the curvature of the upper anterior teeth and the curvature of the lower lip during smiling.

Personality. The rugged, massive individual requires a greater degree of prominence of position vertically and anteroposteriorly. The delicate and the petite need recession of position for harmony. The rugged requires less curvature; the sky-line tends toward a straight line.

Age. At about the age of 50 the incision should be at about the same level as the stomion. The teeth are dropped in position from this level for the young and are raised in position for the elderly. The rule is, the younger the patient the more prominent the teeth, and the more elderly, the less prominent.

Proportion (Size)

After position, the proportion or size of the teeth needs scrutiny—how wide, how long, and how thick? Of these three dimensions, width is the most important, for generally, when the width is known, the other dimensions may be appropriately determined. We are fortunate to have the following hypothesis (advanced by M. M. House), that the bi-zygomatic width of the face divided by 16 will generally result in a pleasing central incisor breadth. Victor Sears counsels a ratio of 18 to 1. My esthetic sense and clinical observation inclines me to employ 16. Occasionally when we are dealing with a decidedly round-headed (brachycephalic) patient, the bi-zygomatic width is divided by 17 instead of 16. The employment of this concept will result in more appropriate width than the concept of measuring from canine to canine on the denture models in order to obtain the combined width of the six anterior teeth. The canine to canine rule is unsound in principle, for size of the anterior teeth is related solely to the size of the head and face and is not related to the position the anterior teeth may occupy in the dental arch.

House divides the length of the face (from the adolescent hairline to the symphysis) by 16 in order to obtain the length of the central incisors. Sears selects a length proportionate to the length of the face proper as measured from glabella to gnathion.

As noted above, there appear to be two concepts as to what constitutes the length of the face to which the length of the anterior teeth should be appropriate. One concept has it that, anthropologically considered, the forehead should be excluded because the face proper extends downward from the glabella. The other concept measures length from the hairline down, that is, it employs the visible face rather than the face proper.

We are inclined to feel that since our endeavors are in the realm of appearances and not actualities, the visible face should be the deciding factor. We would go even further and advise that where there has been a recession of the hairline, a slight increase in tooth length may be desirable, for the upward and backward march of the hairline has the effect of increasing the apparent length of the face while decreasing the apparent distance between the nose and the chin.

Not until I became aware of this illusion did I realize how dangerous it is to build into dentures an occlusal vertical dimension based on appearance. Not only the receding hairline but also the sagging cheeks create the impression esthetically that the bite should be opened more. The conversion of cheeks into jowls is accomplished by a downward and outward movement of the youthful cheeks. The sagging cheeks cause the lower third of the face to appear broader, which in turn causes the relative length to appear shorter.

It is important, at this time, to decide which concept of face length one is inclined to accept, the actual or apparent. I am not unaware of the difficulty, for we dentists have had essentially a scientific training. It is difficult for us to view the situation as an artist who is concerned with the apparent rather than the actual. However, in my opinion that is what we will have to do to see our problem aright.

While the actual face is divided into two parts, the apparent face is divided into thirds. The actual face extends from the glabella to the gnathion, being divided into an upper and lower half by the subnasion. The apparent face extends from the adolescent hairline to the gnathion and is divided into upper, middle and lower thirds by the glabella and the subnasion.

Failure to understand the problem may result in our incorporating a greater occlusal vertical dimension in the dentures than muscle length and tonicity will allow. Our reason for doing this will be because of the apparent lengthening of the upper and middle two-thirds of the face (by a receding hairline), and the apparent shortening of the lower third by the drooping and broadening of the cheeks.

This brings up the matter of what to do about sagging cheeks, drooping corners of the mouth, creases and folds in general. An insight into the remedy is perceived when we consider the cause of these senile facial changes. The loss of teeth and alveolar housing will partially destroy the scaffolding essential to the support of the medial portion of the mouth. The lateral portions of the mouth, including the corners, are influenced by factors other than the teeth and their supporting bone. The sagging cheeks, carrying with them the corners of the mouth, are partly to blame for the appearance of the lateral aspects of the mouth. The remedy lies in plastic surgery to retract the cheeks upward and backward toward their original position. I have found it helpful to explain this fact to the patient, demonstrating on my own face the changes due to loss of tissue tone and texture. Plumpers will have to be employed to please some patients. These lateral masses of denture base material somewhat alleviate the problem of the drooping mouth with its enveloping creases and folds. But they do so at a price—the price of decreased denture stability and malposition of

the mouth. Plumpers cause the mouth to appear straighter, the corners of the mouth being placed anterior to a position essential for an esthetic horizontal curve.

Where ridge contour provides sufficient space, it is advisable to select anterior teeth that are fairly thick. Teeth with depth are less altered in color when processed with denture base materials. They also enable the dentist to vary the tilt or inclination of the anterior teeth without the danger of denture base material showing in the proximal spaces. Teeth with depth enable us to create a dental composition that possesses a third dimension. We thus avoid appearance of flatness resulting from the use of thin teeth.

Effect of SPA Factors on Proportion. *Sex.* This factor has an important affect on the relative size of centrals and laterals. For women there should be a 2 to 3 mm. difference between the width of the central and the lateral incisors. A much smaller lateral confers to the appearance, as Sears contends, a marked femininity, whereas laterals almost as broad as the centrals confer ruggedness and masculinity.

Personality. The rugged individual has a minimum of difference in size between centrals and laterals; the delicate, a maximum of difference.

Age. Generally, age causes the teeth to appear smaller owing to proximal and incisal wear. However, in the absence of incisal wear the teeth may appear longer and narrower because of alveolar bone resorption and subsequent exposure of the roots of the teeth.

Brightness (Color)

The reason why "brightness" was chosen instead of the usual word, "color," is merely one of emphasis. Brightness, brilliance, luminosity and value are all synonymous terms. They constitute one leg in the tripod of color. The other two legs are hue and saturation. As far as the teeth are concerned, the dimension of color that we perceive when we behold teeth in the mouth is brightness. Are the teeth light or dark in relationship to the lightness or darkness of the surrounding facial skin? There is so little actual color in a tooth, that is, so little saturation of the hue (generally yellow) that one has to scrutinize the teeth to detect it.

The importance of translucency in the color effect of anterior teeth should be noted. Translucent teeth will appear more brilliant in hand and less brilliant in the mouth, for color is markedly modified by the source, type and intensity of light. Thus it is wise finally to view the dental composition in the mouth with open and half-shut eyes, and in natural and artificial light of varying intensity.

Effect of SPA Factors on Brightness. *Sex.* Women generally require brighter teeth than men, primarily because of lighter skin complexion.

Personality. The more rugged the personality, the darker the teeth. This is the rule, but exceptions must be made in accordance with complexion. The delicate personality generally has lighter skin and, as a consequence, will require lighter teeth.

Age. Age is an important factor in influencing brightness. The rule is, brightness for youth and dullness for the aged. However, this rule should be modified by the skin status of the individual, regardless of his or her age.

Inclination (Tilt)

This factor is in reality a phase of position. It is given a separate heading for purposes of clarity and emphasis. When the teeth are positioned in the arches, moving them bodily would be translation and would constitute a change of position. However, rotating teeth on their axes (vertical, sagittal or transverse) would change only their inclination or tilt. We may, by rotating or tilting, alter markedly the appearance of the dental composition.

Only under one circumstance will the apparent and the actual dimensions of a tooth be the same, namely, when its labial surface is perpendicular to and on the same level with the line of vision of the beholder. Thus, when we rotate a tooth mediodistally or depress or advance its neck portion we bring into play the law of parallax, which results in an apparent narrowing or foreshortening. Asymmetry, which contributes much to naturalness, may be promoted by varying the inclination—asymmetry of color as well as of mass, for a rotated tooth will reflect and refract light differently, and thus through highlights vary in color.

Effect of SPA Factors on Inclination. *Sex.* Sex has a decided influence on the pitch of the anterior teeth. Women's teeth are usually inclined centripetally, men's usually centrifugally. I have seldom seen a female dental composition that looked pleasing where the teeth did not have a vertical or slightly lingual tilt. The necks of beautiful female teeth are so set that they are further forward than their incisal edges. Men generally have a slight labial inclination in the arrangement of their anterior teeth, which appear to radiate outward.

Personality. The more rugged the personality the more centrifugal in arrangement; the more delicate, the more centripetal.

Age. Age has the effect of lessening femininity and the centripetal composition. As one gets older, the tendency is for the teeth to fan out and become centrifugal in setting. Inclination in the three planes,

horizontal, sagittal and vertical, is more marked in the elderly than in the youthful patient.

Surface Detail and Texture

The surface characteristics of a tooth will influence its over-all appearance, whether its surface is plain or irregular, its mat glossy or dull. Small ridges and grooves on a tooth surface will affect its color. Highlights and shadows will modify the apparent size and shape. A smooth, glossy tooth surface tends to enhance size because the tooth will appear lighter and, as a consequence, larger. An irregular, dull finish will cause the tooth to look darker and, as a consequence, smaller.

Effect of SPA Factors on Surface Characteristics. *Sex.* Generally a woman should have smooth, glossy, curvaceous teeth. The only exception is when her facial skin texture is coarse. A pitted skin detail may necessitate changes in surface factors varying toward the masculine. A man usually has more irregularities in the surface of his teeth and the surface is not as glossy. These suggestions are based on skin conditions. If skin characteristics of a man approach those of a woman, then surface details of his teeth may also tend toward the smooth and glossy.

Personality. Teeth with irregularities of surface detail will be appropriate for the rugged personality, whereas smoothness of planes is more harmonious with a delicate personality.

Age. The aged possess teeth that through wear and tear generally appear rugged and dull.

Outline Form

This factor is placed last on the list because in my opinion it may be ignored with less effect upon the appearance of the dental composition than any one of the prior named factors.

The above statement should not be construed as a disparagement of the concept that a harmonious relationship exists between tooth form and face form. My point is that this factor is not as apparent as the other tooth factors.

While it is probably true that square faces have square teeth, tapering faces have tapering teeth and ovoid faces have ovoid teeth, the emphasis of this factor by tooth manufacturers may have been a disservice. It has tended to undervalue the importance of position, proportion, and pitch in the over-all appearance of teeth. As Roland Fisher has pointed out, the outline of a tooth may be altered by its

wax matrix. The same tooth may be made to appear square, tapering, or ovoid by its enveloping festoon.

In practice the requirements of this factor may be satisfactorily met by the use of blended forms and the avoidance of the severe typal molds. House examined nearly 3000 teeth and found that 42 per cent of them possessed ovoid tapering outline form. The above form combined with the ovoid square and the ovoid square tapering will satisfactorily harmonize with the face form of nearly seven patients out of ten.

One may try the following plan with satisfactory end results. Select a central incisor of proportions harmonious with the face of the patient. Obtain it from the section of the mold guide marked "ovoid tapering." With a disk or carborundum stone, slightly grind the sides to simulate approximal wear and also to confer to the tooth some square characteristics. This tooth will be so bland in outline form that when it is properly positioned and pitched, there will be little or no danger of obvious inharmonious effects. I. R. Hardy invariably employs anterior teeth with convex labial surfaces, that is, teeth that are ovoid in profile view. It has been his observation that a curved surface of porcelain or plastic will reflect and refract light more nearly like a natural tooth and as a consequence will enhance the naturalness of artificial teeth.

Effect of SPA Factors on Outline Form. *Sex.* While outline form of a tooth depends on face form, sex has the tendency of favoring the use of the ovoid tapering for women and the ovoid square for men.

Personality. The rugged, aggressive personality would tend toward the use of square teeth, while the delicate, petite personality would modify the anterior teeth towards the tapering and ovoid or their combinations.

Age. The young generally require tapering and ovoid characteristics in their anterior teeth. The aged, owing to wear and gum recession, frequently are well harmonized with anterior teeth that are generally on the square side.

THE STAGGERED PORCELAIN AND PLASTIC SET-UP

While this article deals primarily with the principles involved in the appearance phase of denture construction, the following helpful procedure should be recorded. I have spoken of this procedure before many groups but have failed up to now to write about it. It is the use of porcelain and plastic teeth in a staggered set-up.

Teeth of appropriate size and shape and color are selected from a porcelain mold guide. With the porcelain central incisor and canine

in hand we go to a plastic mold guide of a different manufacturer. Using only the eyes as a guide, we proceed to select a plastic set about the same size and shape. Two sets of anterior teeth, one in porcelain and one in plastic, are ordered for each case. After individual modifications, a set of staggered teeth is selected. When these teeth are appropriately positioned and pitched, the porcelain and plastic combination confers remarkable naturalness to the dental composition. This is due to slight variations in size, shape and shade—variations that only a true artist could achieve from a single set.

SUMMARY AND CONCLUSION

Six factors are responsible for the organization of the dental composition. They are: position, proportion, brightness, inclination, surface detail and texture and outline form. Position is by far the most important factor, outline form the least important. It has been unfortunate that there has been so much silence about position and such shouting about outline form.

The appearance phase of denture construction presents a dentist with an opportunity to play the role of an artist. The chance to employ and to develop one's innate artistic talents is no small opportunity, and it should also be recognized that it is on the basis of what a piece of oral prosthesis does to facial appearance that one may soundly justify an appreciable differential in fees. For it is conceivable for two sets of dentures to be identical in their mechanical aspects, but it is inconceivable for two men to produce identical esthetic and cosmetic results. There are too many variables in background, mood and temperament. Two men would have to feel alike to create alike.

The dentist who does not take full advantage of the opportunities in the fine arts that organizing the dental composition provides is both improvident and unwise. He is casting aside a taste of an experience that has caused men of every age to sacrifice the security and satisfactions of a normal life in order to feel this joy of artistic creation.

269 S. 19th Street
Philadelphia, Penna.

Open Bite from the Prosthetic Point of View

Jerome M. Schweitzer, D.D.S.

Open bite may appear in any of the classes of malocclusion, although it is more often found in class I. It is characterized by the presence of space between the upper and lower teeth anterior to the first or second molars; the upper and lower incisors and canines are most often involved. It may be due to overeruption of the posterior teeth or failure of the anterior teeth to reach their occlusal level (infraversion). Many of the early workers recognized that hereditary cases of open bite were rather uncommon and spoke of etiologic factors of vague origin which often prevented successful treatment. Blair and Ivy[1] presented evidence of early rickets as an ordinary etiologic factor. Dewey and Anderson[2] related the open bite with an interference to vertical growth as a result of an obscure cause or group of causes and did not associate it with any particular habit. Such general factors as metabolic disturbances, heredity, intrauterine influences, maldevelopment of the mandible, maxillary or mandibular insufficiency, disharmony of the temporomandibular articulation, endocrine complications, muscular activity or inactivity and childhood disorders have been given as causes of open bite.[3] Where the mandible has drifted into a protrusive position in order to attain maximal function in a malocclusion or where the mandibular teeth have been incorrectly related to the maxillary teeth in a false protrusive position by the dentist, the correct posterior positioning of the mandible results in an anterior open bite (Fig. 1). This sometimes makes it necessary to reduce the vertical dimension instead of increasing it in order to attain maximal contact and equal distribution of force at a normal centric relation. Treatment produces stable results in these cases.

In Angle class III malocclusions there is sometimes present an open bite from the bicuspids forward (Fig. 2). This is due to a disparity between the sizes of the arches associated with a growth and development problem, and can usually be corrected either by surgery or by prosthesis or, better yet, by a combination of surgery, orthodontia and prosthesis.

It has been reasoned that occlusal tooth elevation would always take place if it were not for some contact which prevents further elevation. This contact may be either opposing teeth or tissue, such as the tongue. The degree of the opening will depend upon the thickness of the tongue. Lip biting, finger biting or holding a pipe between the teeth may prevent occlusal elevation. Prosthetic appliances which are

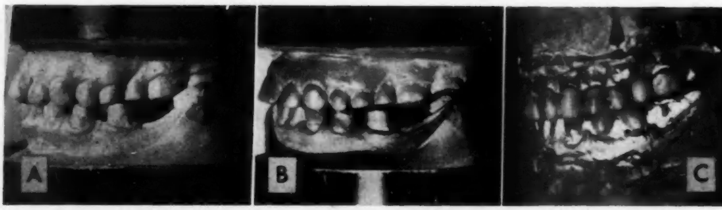

Fig. 1. *A*, Case of reconstruction. The mandible is in a forward position. *B*, Correct position of mandible, anterior open bite resulting. *C*, Teeth reconstructed to this position. Platform built on upper incisors to provide contact for lower incisors.

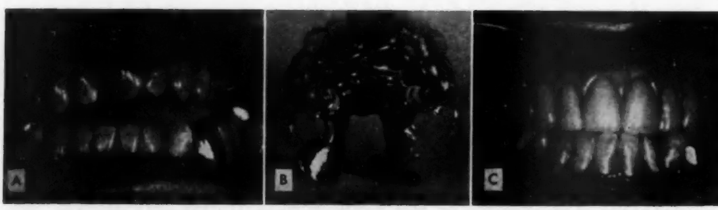

Fig. 2. *A*, Angle class III malocclusion. Only molars contact. Large open bite. *B* and *C*, Prosthetic appliance inserted over incisors and bicuspids to close open bite and provide contact. Esthetics is also an important factor, as is speech.

too high permit the overeruption of and alternate depression of opposing segments of the arch and can be responsible for open bite.

THE GROWTH FACTOR—DEVELOPMENTAL ANOMALIES

Infra-occlusion has been considered as a developmental anomaly due to a perturbation or irregular variation of growth forces. Hellman attacked open bite as a growth problem and placed great significance upon the height and depth of facial dimensions and their effect upon the position of the face. He observed that in open bite cases, the face as a whole was longer in the skull with malocclusion and that the ramus and body of the mandible were shorter. This also contributed to a more obtuse mandibular (gonial) angle than in the normal. He

saw no arrest in the development in the incisal region and stressed the growth factor: "It would seem that growth is the predominating factor in the establishment of occlusion, as it is in the development of the entire individual. But growth is not constant and definite. It varies in intensity, it varies in different structures and in different parts of the same structure. . . . But growth cannot be controlled. It is, therefore, also necessary to recognize our limitations."[4]

There are those who believe that most open bites are caused by deformation of the skeletal pattern. In micrognathism and in acromegaly, the gonial angle is larger than normal. In the former condition, the ramus is short and the condylar growth has stopped. The chin is retruded, with a resulting open bite. In acromegaly, the larger gonial angle and the enlarged protruded mandible results in an open bite. The size of the gonial angle depends upon the proportions between the height of the face and the ramus height. With an increase in facial height, the gonial angle becomes more obtuse. This takes place in many cases of open bite.

Where the open bite is a result of a distortion of the skeletal pattern or an inherited pattern of growth, as is sometimes seen in families, fairly stable results are possible at the termination of prosthetic treatment. In some cases of this type the vault of the palate is extremely high, the maxillae are very narrow in the bicuspid and molar regions, and there are protruding upper incisors. In these cases the mandible is very wide in the bicuspid and molar area, and posterior crossbites often exist. Where the patients are content with the esthetics, these cases are best not disturbed because, although in apparent malocclusion, they are in muscular equilibrium and it is dangerous to upset this balance.

Another type of case which should be approached with caution is that in which the open bite extends from the molars forward and contact is only apparent in the molar region. These patients also possess an unusually large and active tongue, and the lips and cheeks are flabby and excessive. It is difficult to see the teeth when treating these cases because of the excessive and active tissues. Experience has shown that when this type of open bite is closed either by grinding the molars down or by building up the upper and lower teeth to contact, in a comparatively short time the open bite is once again re-established (Fig. 3). This may be due to a continuous eruption of the molar teeth, in addition to an anterior thrust of a powerful tongue. The tongue moves forward and outward and with this strong muscle placed between the upper and lower teeth, the jaw bone can actually be bent (since it is plastic), with the greatest effect taking place anteriorly. The result is a continuous opening of the bite in spite of our best

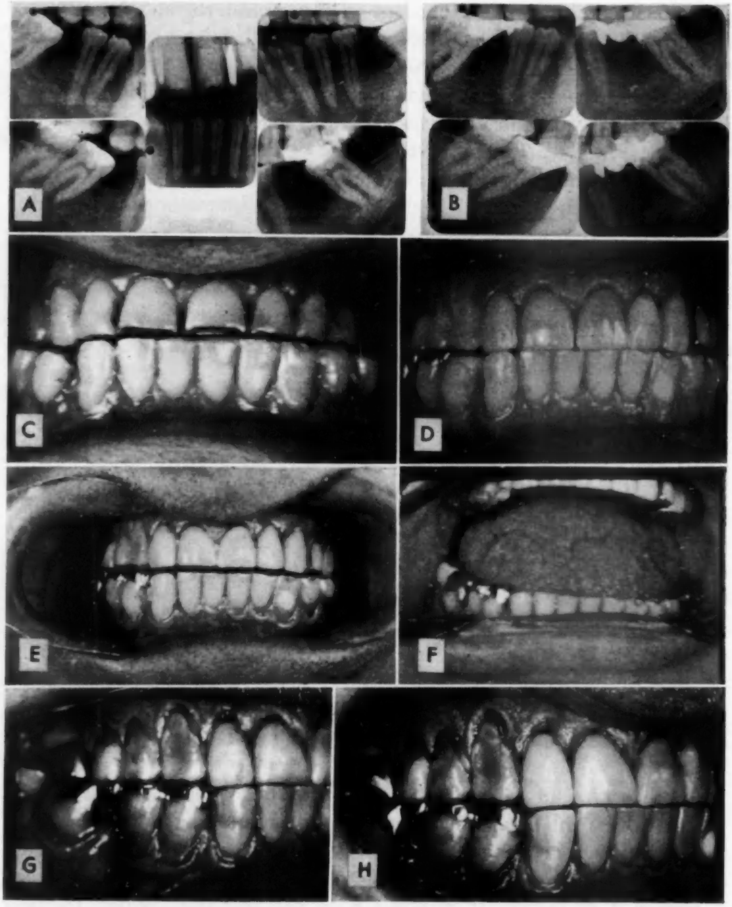

Fig. 3. *A*, Adult male in 1934, only rear posterior teeth occluded. *B*, Bite was closed by grinding molars down and inserting fixed bridges. *C*, In 1940, bite was once again open. *D*, In 1940, occlusion was reconstructed by raising vertical dimension and placing porcelain jackets on the anterior teeth. *E*, In 1954, bite was once again open. *F*, Observe large tongue. *G*, In 1955, bite was closed by grinding posterior teeth. *H*, In 1956, bite is again starting to open.

efforts. In some of these cases the teeth are so scoured by the tongue that, in addition to the open bite, there is also manifest an abrasive or erosive effect on the teeth.

One must not lose sight of the fact that these open bites, some of which are so difficult to understand, can be caused by a continued

growth of the head of the condyle which would drive the mandible downward and forward.

The assessment of the open bite has been made, in some cases, on the position of the condyles. An inferior displacement of the condyle head would indicate a supra-occlusion of the molars. Infra-occlusion of the anteriors would be indicated by a normal position of the condyle head. Where grinding of the molars is to be resorted to in an effort to close an open bite, this assessment of the position of the condyle is a valuable guide to treatment.

Open bite may be due to the forward positioning of the entire maxillary denture. In this instance, the anterior segment from canine to canine would manifest the greatest discrepancy. Macroglossia, microglossia, and ankyloglossia (tongue tie) have been reported to result in arch collapse (microglossia) and spreading and spacing and loss of proximal contact (macroglossia).

Where an open bite is the result of a growth pattern in which the gonial angle is more obtuse than normal there is apt to be an elongation of the bony processes in the facial areas. The free-way space in these cases is very small. This should be taken into consideration in treatment.

There is a primary genetic pattern which is responsible in a general sense for the form and shape of the various body structures, but it is the oral musculature—the tongue, the lips, the cheeks—which is effective in molding the arches and in checking the vertical growth of the teeth. The teeth are positioned anteroposteriorly, laterally and vertically by the muscles so as not to interfere with their action, and both arch form and tooth position and inclination must be in a neutral muscular zone to attain stability.

Normally, osseous and muscular growth keep pace with each other. Sometimes the muscular pattern will forge ahead of the skeletal pattern, and then we may expect a flaccidity of the muscle system. On the opposite side the muscular growth could lag behind the skeletal growth, in which case there would develop a tenseness of the muscular system. In addition, if there were lack of harmony between tooth eruption and jaw growth, our whole picture could be complicated.

Endocrine Disturbances

Deformation of the skeletal pattern may result from endocrine disturbances. Investigation has shown "that if a new layer of hyaline cartilage has developed, endochondral growth can again set in after resorption of the terminal plate. As in other bones, the periosteal appositional growth is stimulated by the growth hormone; but this

growth does not keep pace with endochondral growth, and the effect is a gradual increase in the mandibular angle."[5]

Open bite has been observed in some cases of juvenile dwarfs. The mandible is often insufficiently developed, with resulting crowding, overlapping and malposed teeth. It is also sometimes seen in the case of anterior lobe hypopituitarism. In these cases, speech is often defective.

Ankylosed Teeth

Open bite can be caused by ankylosed teeth whose eruption has been arrested. The cementum of such a tooth is fused to the surrounding bone, and periodontal membrane is lacking. Open bite may also result from joint dislocations and scar contraction following burns of the face, as well as from ankylosis of the temporomandibular joint.

ORAL HABITS

Abnormalities of Tongue Pressure and Faulty Deglutition

There are others who believe that most open bites are not caused by a deformation of the skeletal pattern but rather as a result of the perverted use of the tongue in swallowing. In normal swallowing, the dorsum of the tongue is in contact with the hard and soft palates, exerting its pressure against them in an upward and lateral direction. Its tip and edges do not protrude between the teeth at any point. The tongue does not rest upon the incisor teeth in normal swallowing.[6]

"In open bite cases the tongue does not arch up in the palatal vault but lies flat in the mouth. Due to this lack of arching it needs more room laterally and therefore, protrudes anteriorly and causes the maxillary incisors to be pushed forward, upward and outward. In some cases, it extrudes laterally between the posterior region. There may be many combinations and variations."[6] An acrylic appliance has been suggested to correct this by directing the tongue into a sleeve in the anterior portion of the palate and preventing its intrusion between the teeth.

Jackson[7] states that there is practically always a tongue habit in connection with open bite cases and any type of appliance that will aggravate the misuse of this unruly organ must be avoided. From the anatomic standpoint, he suggests depressing the molars and elongating the incisors. Retention of these cases is very difficult. A double screen has been devised for this purpose by the late Dr. Oscar Henry, of

London. Another method of treating open bite in children is by the use of a cuspid to cuspid lingual bar with spurs attached. This, together with lip exercises, proves effective in some cases. Straub[8] made a clinical study of 237 patients with an abnormal swallowing habit. He found that all of them were bottle-fed babies, and attributes the perverted swallowing habit to improper bottle feeding. In many of these cases the anterior segments of the arches were affected. Open bites and protrusion of the upper anterior teeth were common. Many of the children were also thumb suckers. The palatal vault was narrow and the tongue was accommodated in the lower arch. The picture is that of a narrow upper arch, a severely contracted maxilla, protruding upper teeth and an open bite relationship.

Swinehart[9] minimized the growth factor while stressing the abnormal pressure of the tongue as the causative influence in open bite. He pointed out the danger of thumb and finger sucking. The spaces between the arches which are caused by thumb and finger sucking compel abnormal action of the tongue. Abnormal action in deglutition is given as an originating cause in some cases and is considered as a perpetuating factor in all cases. It had already been stressed by Heath in 1894 that the size of the tongue was responsible to a great degree for the size of the dental arches. Cases were reported thirty years ago of the congenital absence of the tongue and the subsequence of collapse of the mandibular arch together with the greatly underdeveloped lower third of the face and the recession of the chin. The effect of the absence of the tongue is seen not only in the alterations of the arch and tooth alignment but also upon the entire skull.

The tongue must function properly if arch form is to develop normally. Holding the tip of the tongue between the incisors during swallowing can result in infraversion. Most of these cases of improper tongue function should be treated before adolescence. Complete absence of the tongue may seriously affect mandibular development.

The tongue grows very slowly. It has a three-point suspension bilaterally on the cranial base in the region of the mastoid and styloid processes and anteriorly on the mandible in the region of the symphysis. Brodie[10] considers that the tongue within and the buccinator without position the crowns of the teeth, and that it is the size, position and form of the tongue and the effective tonus of the buccinator which are the determining factors. The tongue at birth is probably closer to adult size than any other part of the head with the exception of the brain, and therefore, being so well developed before any of the surrounding structures, it must exert a great influence upon the development of the arches. If there is a great disparity between muscular

and osseous growth, an open bite may result. This condition may sometimes be corrected without treatment if jaw growth catches up with tongue growth.

Whitman[6] has observed that one of the most common causes of improper use of the tongue is the artificial nipple used in the bottle feeding of babies. He states that this nipple is ¾ to 1 inch in length and its counterpart cannot be found in the human female. Its use modifies the entire sucking habit and thereby induces faulty swallowing. In conjunction with thumb sucking, it creates a vicious cycle.

Faulty deglutition has been cited very often as the cause of open bite. Atkinson prescribes the following method of detecting an incorrect swallowing habit: "Hold your hand on the chin of the patient while the patient is in the act of swallowing. If the jaw is opened during the act of swallowing, it is an indication that the swallowing is done improperly. If the jaw opens during the act of swallowing, the suprahyoid muscles will pull the body of the mandible downward, bending it just anterior to the angle the jaw causing a tendency for an open bite. If the jaws are closed during the act of swallowing, it is impossible to produce this bending of the mandible just anterior to the angle of the jaw. Open bites are all typical—bent down just anterior to the angle of the jaw."[11]

There are many different ways in which the results of a faulty tongue habit together with a tongue of unusual size and faulty methods of deglutition manifest themselves clinically in adult patients who are in need of dental prosthesis. In some cases an open bite is present anteriorly, while in others it is present posteriorly. The anterior open bite may be accompanied by a vertical and horizontal overbite. The posterior open bite may be bilateral or unilateral.

Many of these patients have a speech impediment. In some patients the lower molars have a buccal inclination due to the tongue thrust, while in others the upper molars have a buccal inclination of their crowns. The lower incisors are rotated and spaced. This is more severe in older patients than in younger patients and continually gets worse as the patient grows older. Non-contact between the upper and lower teeth may be slight or great in different subjects. These cases are difficult to work on. The large and powerful tongue is constantly in the way, and, even though the patient is cooperative, the difficulty of tooth preparation and of performing the necessary dental operations taxes the ability and energy of both dentist and patient alike.

In adults where the tongue is the offender and false swallowing has been practiced for many years, the correction of these well established neural patterns is difficult, if not impossible. If the spaces between the teeth are closed, the tongue will continue to push and thrust and

deglutition will be hampered until enough space is again created to permit a continuation of the long-established habits. (See Fig. 4.)

It is necessary, therefore, for our prosthesis to permit sufficient space for tongue movement which was present in the pretreatment condition (Fig. 5). Some operators claim to prevent old habits from reasserting themselves by splinting an entire group of teeth together. Here, again, it must be remembered that muscle is the dominant factor and that bone is subordinate to muscle. In many of these cases of splinting,

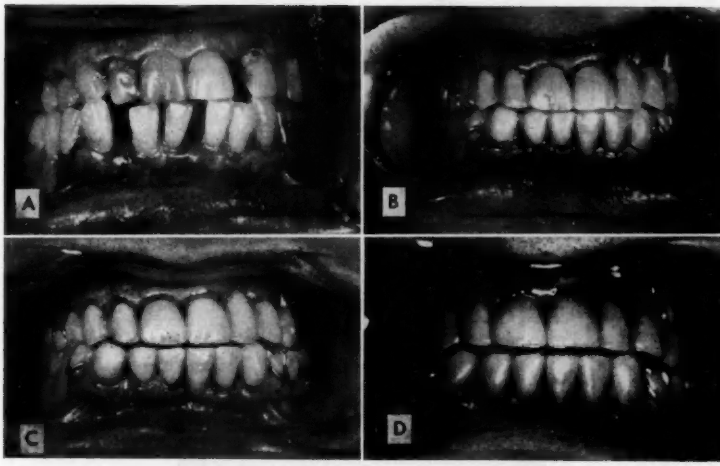

Fig. 4. *A*, Female, 60 years old. Spaced anterior teeth. Wide arch. *B*, Case reconstructed. Lower and upper anterior teeth splinted together. Observe contact of upper and lower teeth. *C*, One year later. Entire anterior splints moved forward and open bite present. This was corrected by grinding. *D*, Two years later. Once again, open bite present due to tongue thrust.

the entire splint, if placed in the anterior section of the arch, is moved bodily forward and the open bite is again re-established. In the posterior regions, in addition to moving the entire splint buccally, the teeth may even be depressed so that once again the open bite is manifest.

Some open bites follow tonsillectomies, owing to the development of incorrect swallowing habits following the operation while the throat is sore and swallowing is difficult. In these cases, tongue and speech training is important in treatment.

In adults in whom the tongue and faulty swallowing habits have caused the open bite, the treatment plans must provide for sufficient room for the continued pernicious habits to continue (Fig. 6), otherwise the results will not be stable in most cases. Operation to reduce

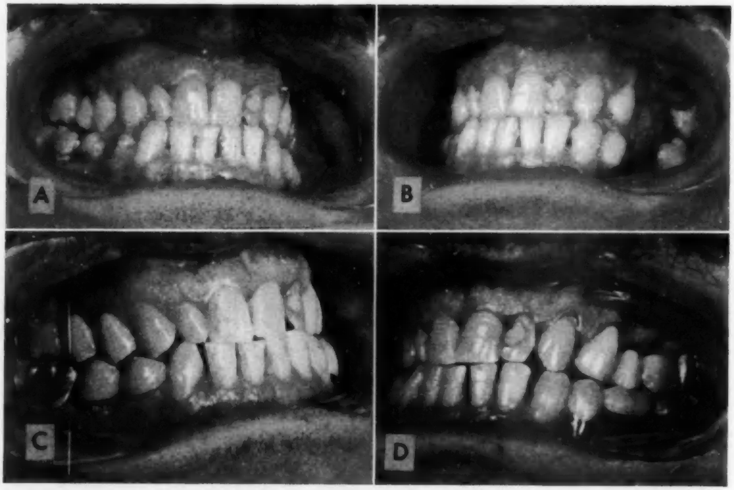

Fig. 5. *A* and *B*, Male, age 43. Posterior open bite due to tongue thrust. Wide mandibular arch. Spaced lower incisors. *C*, Right side reconstructed, small spaces retained for tongue to have sufficient room. *D*, Left side reconstructed. Bridges are open beneath dummies to permit tongue thrusting and prevent relapse.

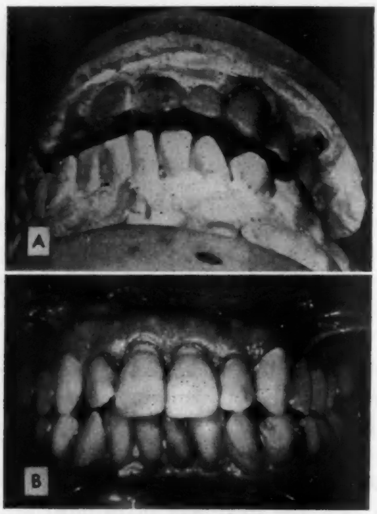

Fig. 6. *A*, Fixed bridge replacing upper left first bicuspid. Adult female with anterior open bite. Observe that the open bite is maintained. *B*, Bridge inserted in the mouth. The opening is maintained to permit the tongue thrust.

the tongue size has been suggested, but this must be undertaken only in unusual cases. The tongue reaches a very large size in early childhood, and is much further advanced in growth than its surrounding tissues. Usually, these tissues catch up with it, but if they lag behind in their growth spurt then the larger tongue can and does cause malposition of the teeth. A long, narrow tongue results in a long, narrow arch. The tongue is a definite molding factor. In addition, a large and active tongue may cause mechanical abrasion of all the teeth, as is sometimes seen in severe cases of tooth wear. In acid erosion such as is sometimes seen in drinkers of lemon juice in warm water or cola drinks of various kinds, the tongue is capable of scouring the softened tooth structure and reducing its size. This can cause complete non-occlusion at normal levels.

Thumb Sucking

Where thumb sucking is the cause of open bite, a method of treatment whereby a palatal wire screen is attached to the right and left first molars by two bands has been effectively used. This screen prevents the thumb from forming an air-tight seal by breaking the vacuum and permitting air to enter. Thumb sucking is difficult to cure and may persist into adulthood. It is significant to both the psychologist and the dentist.

Faulty tongue habits and faulty methods of swallowing are the most difficult conditions to deal with in adults, and many orthodontists state that these habits are even difficult to correct in children. All methods of breaking these habits have been employed, including psychotherapy. Thumb sucking usually is discontinued at about 18 months and cases due to this habit may then be treated, but if this habit continues into adulthood it becomes a serious menace to the problem of the open bite.

MISCELLANEOUS FACTORS IN OPEN BITE

Hypofunctioning Pharyngeal Reflexes

Some open bites are the result of the non-functioning of the pharyngeal reflexes. In these cases, there is absence of gagging even when the pharyngeal walls are touched with a mirror. These patients are slower to respond to treatment because they cannot feel how to swallow the newer and correct way. This condition is called "anesthesia throat" and was described by Dillon in 1945.[12] The patients swallow only with conscious effort.

Riesner believes that "'diminished pharyngeal reflex' is a better name than anesthesia throat or tongue, inasmuch as it is not a state of anesthesia of the throat or tongue but rather a diminished reflex action of the pharynx which moves posteriorly when the tongue is humped back in deglutition. When this reflex is not sensitive, the tongue strikes an unyielding wall of the pharynx and is propelled forward, coming to rest between the anterior teeth. The force of this pressure is powerful and as the insult is continued produces an open bite."[13]

Nasorespiratory Obstruction

It has been held that obstruction of the nasorespiratory area influences the development of the face and that adenoid growth complicates the facial pattern development by constricting the nasopharyngeal passage. If there is a disturbance in the growth balance and the development of lymphatic adenoid tissue increases in mass faster than the palate drops, there will be a blocking of the nasopharyngeal cavity with a resultant change in the position of the tongue and soft palate. The air passage must be cleared so that the dorsum of the tongue is now forced downward and forward away from the soft palate. Air now passes from the oral cavity into the oral pharynx. The lingual pressure exerted by the tongue upon the upper posterior teeth is no longer present. The maxilla is narrowed, the palatal vault is high, the upper anterior teeth protrude, and an open bite is often present. Breathing must be done through the oral cavity instead of through the nose, and this has a detrimental effect upon the denture. The mandible is depressed.

Diet

Diet has been suggested as an etiologic factor, and it has been pointed out that muscular hyperirritability, which occurs in rickets, with the concurrent softening of bone causes exaggerated pressures in the masseter and internal pterygoid muscles which form the mandibular sling. This excessive pressure tends to produce an obtuse gonial angle at the junction of the ramus and body of the mandible. Moreover, the new shape of the mandible is likely to be the pattern for later growth, even after the deformity has been eradicated.

Faulty Dental Appliances

There are also those cases of anterior open bite which may be caused by faulty dental appliances. In their effort to correct a deep

vertical overbite, dentists have placed removable onlays over the lower posterior teeth. In those cases in which the anterior teeth were left with an open bite, the posterior natural teeth were depressed. The result was a posterior open bite if the appliance was removed (Fig. 7). This type of open bite can be corrected by rebuilding these teeth to occlusion with onlays. Another method would be to remove sections of

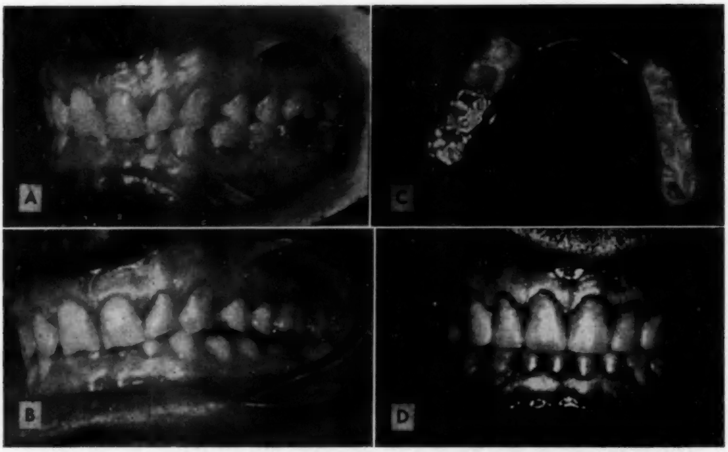

Fig. 7. *A*, Male, 35 years old, is wearing a removable lingual bar with onlays over his posterior teeth on both right and left sides. This was inserted by his dentist to correct a deep vertical overjet. Within 18 months, the overjet returned to its original depth. *B*, When the appliance is removed, the depression of the posterior teeth is evident. This open bite was caused by the dentist. *C*, This is the removable appliance which was worn. *D*, About 9 years later, another dentist rehabilitated the occlusion at the established level. This case now should be stable. The posterior teeth were built up to occlude.

the bridge gradually and permit these depressed teeth to reach their normal occlusal level.

Fracture of Mandible or Condyle

Where the body of the mandible or the condyle has been fractured, open bite may result. These cases can be best treated by a combination of surgery and orthodontia, with prosthodontics sometimes helping. In Angle class III cases, an open bite is usually present. Surgery has been employed to correct this condition, but most surgeons agree that it is better to postpone treatment until growth has taken place; if this is not done, the results have been unstable. Those cases in which surgery has been resorted to under the age of eighteen have usually

had relapses, with a resulting open bite and a forward positioning of the mandible. In addition to the surgical correction of this type of case, orthodontics and prosthodontics must also help in the final coordination of the occlusion.

Muscular Dystrophy

It has been demonstrated that progressive muscular dystrophy will often cause open bite by producing loss of function of the cheek and lip muscles to a degree greater than the loss of function of the tongue.[14,15] This disease causes great changes in arch form. The arch expands and the teeth rotate and space until they finally find a new position of equilibrium.

Chemical Erosion

Some cases of open bite are caused by erosion and abrasion due to chemicals. In this type of case, the vertical dimension is not changed. These cases are stable after they are corrected.

CONCLUSION

The problem of the open bite presents just as many difficulties for the prosthodontist, the surgeon and the general practitioner when it is present in an adult patient as it does for the orthodontist when he encounters the problem in a child. Most of these patients are better treated in childhood. Some open bites are due to growth and endocrine abnormalities, and some are caused by faulty habits, diseases, tongue and tissue abnormalities and faulty methods of deglutition. A great many causes and treatments have been discussed. The tongue has been accused of being the most serious etiologic factor and the most difficult one to treat, in adults as well as in children. When the tongue factor is present, the results of treatment are usually unstable. This, once again, asserts the domination of muscle over bone.

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Diet and Nutrition in the Edentulous Patient

ARVIN W. MANN, D.D.S.

THE PROBLEM

The patient with new dentures has a very real nutritional problem, for during the time his function is severely curtailed (the transition period from natural dentition, to extractions, to the edentulous state, to full dentures) additional dietary restrictions are imposed. These make adequate nutrition very difficult or well-nigh impossible at a time when additional nutrition is vital for healing and repair.

Perhaps at this time the differentiation between "diet" and "nutrition" should be made. Diet is the food that is taken into the mouth. The process of digestion, absorption, assimilation, and finally utilization by the cells themselves constitutes nutrition. This can best be exemplified by the automobile. The conversion of the fuel contents of the gas tank (the diet) to provide a smoothly running motor (healthy metabolism) may be likened to optimal human nutrition. It is of interest to note, however, that other regulatory mechanisms are also essential. The enzyme-coenzyme and endocrine systems (represented by the carburetor) are extremely important to consummate the "miracle of metabolism"—a healthy human being.

It is important to differentiate between diet and nutrition, for occasionally patients on an adequate diet develop nutritional deficiencies because normal digestion, absorption, assimilation and utilization are interfered with or nutrients are destroyed. For example, large doses of mineral oil will coat the gastrointestinal tract and prevent normal absorption of nutrients (especially vitamin A) by blocking or preventing normal absorption. These factors are what Ershoff[1] calls "conditioning factors in nutritional disease."

The novice also faces the additional problem of learning to wear the large and cumbersome dentures and then make them function. This learning process varies greatly with different individuals. It might be likened to driving a car or learning to cook. Some individuals "catch on" rapidly and in no time at all are extremely competent. Others never seem to "get the hang of it" and so never become really pro-

ficient. Factors which largely determine how rapidly the patient becomes proficient are age, health, mental attitude, adaptability of the patient, the perfection of mechanical function arrived at with the finished dentures, and the condition of the supporting tissues. Age and health are extremely important, for young patients seldom have a period of disturbed function as they learn to use the dentures very readily. Older patients, on the other hand, may have a great deal of trouble solving this problem. Ill health and other basic metabolic disturbances also complicate this picture. The mental attitude of the patient may well be a serious handicap when all other factors are favorable. The patient who says, "I just don't think I'll ever learn to wear these teeth" has little chance for success. The dentist can do a great deal for these patients by offering encouragement and advice. Nervous patients frequently develop nervous habits, e.g., "playing with" the denture with the lips and tongue, which dislodges the denture instead of holding it in place.

T. A. Bodine,[2] of Akron, Ohio, has very ably demonstrated the need for training patients so that they might learn useful habits of the tongue, cheeks, lips, etc. The patient who habitually retracts his tongue may be trained to hold it on the lingual surface of the lower denture by standing in front of a mirror, swallowing, and practicing holding the tongue out for three minutes a day. In a short period of time, the tongue will help to hold the lower denture in place instead of dislodging it when the patient is talking or eating. The patient may also be trained to use his buccinator muscles to "chew his cheeks," thereby helping to stabilize the upper denture.

It seems extremely important that the patient's first step should be to tolerate the dentures in the mouth without any attempt being made to masticate with them. Later on, after the bases are comfortable and the patient has learned to manipulate the dentures, soft foods may be chewed and as the patient progresses, normal dietary function will be the goal. Practice chewing with chewing gum, raisins or other dry food may expedite learning to chew. In general, meals for the new denture wearer should include only soft foods although more solid, coarse foods should be added as soon as the patient can tolerate pressure on the denture-bearing area. He should not remain on a liquid diet any longer than is absolutely necessary. Liberal amounts of the "good foods"—meat, cheese, poultry, seafood, eggs, milk, vegetables, fruits, butter and whole grain cereals (these will be discussed in detail later)—should be added to the dietary as soon as the patient can masticate them.

This learning period is perhaps the most critical for the denture wearer, for he will either acquire confidence and proficiency during

this period or will, after several half-hearted attempts, become discouraged and resort to "wearing his dentures in the bureau drawer." It is vital that the dentist do everything in his power to encourage and help the patient over this rough road during this very critical time. P. C. Lowery,[3] of Detroit, Michigan, has advanced a very practical suggestion of allowing difficult cases to wear the dentures for short periods of time, increasing the length of these periods until finally the patient can tolerate the dentures all of the time. During this difficult time, Lowery also recommends that the patients continue to eat a normal dietary by liquefying all food in a Waring Blendor. Since this increases the potential loss by oxidation tremendously, all liquefied foods must be consumed immediately. Substituting this mechanical trituration for normal denture function is recommended only for the short period of time while the patient is becoming used to tolerating the dentures in the mouth and up to the time when the patient learns to masticate. Prolonged use of a liquid diet would certainly be undesirable.

The denture wearer should cut his food in as small pieces as possible before eating, thereby decreasing the amount of trituration required by the artificial dentures. In some instances, smaller servings taken at more frequent intervals (five to six instead of three meals a day) help the patient to maintain normal dietary intake. Bread and tough, coarse foods should be avoided, as they are very difficult to manage.

The art of chewing is quite different, as the new denture wearer soon finds out. The masticatory stroke is decreased in length and the patient works in a narrower range of eccentric movements. This does not restrict the patient's diet, but rather points up the importance of learning to chew; e.g., in biting an apple or eating corn on the cob, the denture wearer will do the reverse of the patient with natural teeth—the object is pressed against the partially opened mouth and held against the teeth while they are occluded. At no time can the object be moved outward, as in the case of natural teeth, without dislodging the dentures. The reverse force tends to settle rather than dislodge the dentures. This "learning to chew" is so very important from a nutritional standpoint because patients who cannot chew adequately restrict their diets and omit the highly nutritious foods, thereby encouraging deficiency disease.

DIETARY ESSENTIALS

The diet is composed of groups of nutrients, all essential to normal cell metabolism and growth. Unfortunately, discipline and intelligence

are too seldom exercised in food selection. We have also lost our instinct for food to a great extent so that we are now selecting food for appearance and taste rather than for its nutrient value.

Nutrients are grouped into proteins, fats, carbohydrates, vitamins and minerals. In addition, adequate amounts of water and roughage are essential for normal metabolism. Energy is measured by calories (heat units), which are usually obtained from carbohydrates and fats, although proteins also may be used. The requirements for the diet are tremendously increased during disease, during the growth periods in infancy and childhood, and in women during pregnancy and lactation.

Carbohydrates

Carbohydrates are of two types: (1) natural (those products of carbon, hydrogen and oxygen which occur naturally in fruits and vegetables and other foods), and (2) refined (those carbohydrates that are refined or processed out of foods in a crystalline state or made synthetically, e.g., glucose is made by the action of H_2SO_4 on starch). Carbohydrates are broken down to monosaccharides and absorbed as such. Denture patients, especially those in the age bracket over 60, tend to eat far too many carbohydrates because they require less mastication. Patients in this age bracket also require fewer energy foods because of their more sedentary life.

Fats

Fats are valuable essential nutrients during periods of excess activity or in cold climates. They supply more calories per unit volume than any other nutrient. Fats are broken down and absorbed as fatty acids. However, it must be emphasized that unless fats are "burned up" or utilized, they find their way into the tissues and produce excess body fat which is often difficult to remove.

Proteins

Protein is perhaps the most important food essential, as only protein can rebuild and replace worn-out tissue cells and thereby maintain metabolic balance. Animal studies have demonstrated the degeneration of the connective tissue structures of the periodontium in protein deficiency.

Protein molecules are large and complex, consisting of combinations of amino acids, nine of which are essential to human nutrition. The others can either be converted from these nine essential amino acids,

or obtained from the diet. Proteins are broken down during digestion to proteoses, peptones, polypeptides, and finally to amino acids and absorbed as such.

Protein deficiency is common in the edentulous patient because he avoids meat because of the chewing effort involved. This bad habit frequently leads to chronic anemia, which is prevalent in the aged.

Milk and dairy products, meat, fowl, seafood, nuts and whole-grain cereals are excellent sources of protein. If it is necessary to increase intake, supplements of wheat germ, brewer's yeast, predigested protein or even amino acids themselves may be used.

Vitamins

Vitamins are organic catalysts which are essential to human metabolism. They are widely distributed in foods but may easily be destroyed by cooking, processing, handling, etc. Although each vitamin acts in a specific way, we are learning that the interaction and interdependence of vitamins, working in groups, is perhaps as important as their specific effect; e.g., vitamins D and A in combination seem to be more effective than when either vitamin is used separately. This interaction is also noted with other essential nutrients, e.g., adequate amounts of vitamin D must be present to promote optimal calcium and phosphorus metabolism.

Vitamins, minerals, and specific proteins are closely interdepedent in making up enzymes and the enzyme systems. Therefore, the discussion of single essential nutrients, be they carbohydrates, fats, proteins, minerals or vitamins is academic, for *ALL* nutrients are essential and *ALL* work together.

Vitamins are divided into fat-soluble and water-soluble groups. Vitamins A, D, E, and K are fat soluble, whereas vitamins of the B complex and vitamin C (ascorbic acid) are water soluble.

Vitamin A. Vitamin A is formed from the provitamins alpha, beta and gamma carotene, and is essential for maintaining the integrity of the epithelial cell. A deficiency of this vitamin causes ocular disturbances (xeropthalmia and night blindness) and skin disorders (hyperkeratosis). The oral structures are involved only in prolonged, severe deficiency states.

Vitamin D. There are some 16 substances related to sterols which vary widely in antirachitic potency. The most important of these are vitamins D_2 (calciferol) and D_3. Vitamin D_2 is formed synthetically by irradiating ergosterol, while vitamin D_3 is produced by exposure of the skin to the ultraviolet rays of the sun. Vitamin D is essential in the metabolism of calcium and phosphorus, hence it is essential for de-

velopment and maintenance of good bones and teeth. A deficiency of vitamin D in children causes rickets, and in adults it causes osteomalacea.

Becks,[4] Bauer,[5] and others warn of the extreme danger of overdosage with vitamin D, especially by chronic excesses over long periods of time. Present evidence indicates that overdosage with other fat-soluble vitamins may also produce severe damage. This is in sharp contrast with reactions to water-soluble vitamins, for even massive doses of the latter apparently produce no harmful effect.

Vitamin E. The role of vitamin E in human nutrition has not been made entirely clear. Evidence has been advanced that it saves vitamin A (decreases the amount of vitamin A required to produce a given result) and that it produces profound effects on lower animals, notably as an antisterility factor.

Vitamin K. The vitamin K group of antihemorrhagic factors (K_1, K_2, K_3, K_4, K_5, K_6) is essential for synthesis of prothrombin and the normal blood clotting mechanism. Both natural (K_1, K_2) and synthetic forms (K_3, K_4, K_5, K_6) are used therapeutically. Prothrombin time is increased and coagulation time prolonged in deficiency states. Gingival bleeding and oozing is sometimes noted.

Vitamins of the B Complex. The vitamin B complex contains many closely interrelated water-soluble vitamins which, acting as coenzymes, are essential for normal respiration of the body cell. There usually is a greater over-all lack in the water-soluble vitamins than in any other group of essential nutrients. This is due not only to dietary deficiency, but also to the great loss of these nutrients by faulty food handling, storage, processing and preparation with "modern" cooking methods. It is interesting to note that Topping and Fraser[6] in their classic studies produced specific lesions of deficiency of these vitamins by placing rhesus monkeys on specific starvation diets.

Niacin (Nicotinic Acid). One of the most important members of the vitamin B complex is the pellagra-preventive factor, niacin (nicotinic acid). Although this fraction is important in carbohydrate metabolism, its function is closely linked with tryptophan, and deficiency causes pellagra. For many years pellagra was known as the scourge of the South. However, with the classic discovery by Elvehjem et al.[7] that nicotinic acid produced a dramatic cure in severe cases of canine blacktongue (a disease in dogs analogous to human pellagra), and its consequent use in humans, the mortality rate has dropped until at the present time it is rare to find pellagra listed as the main cause of death in mortality statistics (e.g., Knox[8] has stated that while in 1931 there were 2820 cases of pellagra reported in North Carolina, in 1941 only 199 cases were reported).

The mouth lesions are quite prominent and are noted early in the course of the disease. The patient complains of a sore mouth and tongue, especially when hot, spicy foods are eaten. The oral mucosa is bright red—even scarlet in color. When teeth are present this redness is more prominent in the mucosa labial to the anterior teeth, especially in the mandible, and returns to normal after therapy. This redness is not as pronounced in the edentulous mouth and when present is usually in scattered "blotches." Ulcers may occur over the ridge areas even though dentures are not worn (Fig. 1A). The tongue shows many

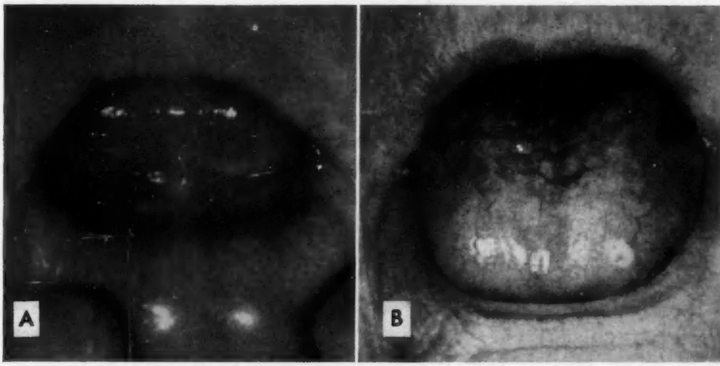

Fig. 1. *A*, Note ulcer over lower ridge in pellagra. This patient has never worn dentures. This might have been mistaken for a traumatic ulcer if the patient had worn a lower denture.

B, Note smooth, slick, gelatinous tongue and angular cheilosis indicating nutritional deficiency disease. Blood chemistry confirmed diagnosis of iron deficiency anemia and again demonstrates the complex nature of nutritional deficiency disease. (Photos by author at Nutrition Clinic, Hillman Hospital, Birmingham, Alabama.)

bright red hypertrophied papillae during the acute stage of the disease, but these are restricted to the tip and sides of the dorsum, in sharp contrast to the general distribution noted in febrile states. As the disease progresses, the papillae atrophy and disappear, the mouth becomes smooth, slick and gelatinous and the disease enters the chronic stage. An over-all redness is usually noted. This tongue will only return to normal after extensive therapy.

It is important to note that completion of the therapy with one fraction and the disappearance of the lesion associated with this deficiency frequently leads to incomplete eradication of symptoms, as other signs and symptoms remain indicating the presence of other fractional deficiency diseases. For example, a patient whose tongue showed marked pellagrous glossitis was treated for pellagra with nicotinic acid with marked but not complete response. Subsequent anti-anemic treat-

ment and panvitamin therapy was required to complete the treatment. This emphasizes the important consideration that *nutritional deficiencies never occur singly. When one occurs, deficiency can be suspected in all other nutrients even though no clinical evidence is present.*

Figure 1*B* illustrates this point very well. This patient had clinical evidence of chronic pellagra and riboflavin deficiency (acute angular cheilosis) and, in addition, her laboratory analyses revealed that she also suffered from iron deficiency anemia. It is interesting to note that the patient's deficiency symptoms started one year after her teeth were extracted. Lost dental function was never replaced, as this patient has never worn dentures.

Glossitis then, is a valuable warning signal but does not necessarily indicate the specific deficiency disease that is present. One must search further with a complete history and physical examination, blood chemistry, urinalysis, gastric analysis and other laboratory procedures before arriving at a correct diagnosis. Time and space do not permit a more complete discussion of glossitis, but the author strongly recommends further collateral reading, especially the excellent work of Vilter,[9] to acquaint the student with this very important phase of oral diagnosis.

Pyridoxine. Pyridoxine is close to niacin in activity and is concerned with the conversion of tryptophan to niacin. Mueller and Vilter[10] were able to produce deficiency states in humans by feeding diets which were grossly deficient in vitamin B complex fractions with the addition of desoxypyridoxine (an antimetabolite of pyridoxine). Clinically, they noted eroded angles and seborrhea-like skin lesions similar to those found in riboflavin deficiency. In some instances glossitis and mucous membrane lesions like those found in nicotinic acid deficiency were noted. Treatment with pyridoxine produced prompt response even though previous treatment with other B complex fractions was ineffective.

Riboflavin. Riboflavin (vitamin B or G) is one of the most important members of the vitamin B complex. Spies[11] believes it to be the most prevalent vitamin deficiency, probably affecting several million people.

Rat studies indicate that congenital malformation of the palate and lower jaw can be induced by maternal riboflavin deficiency. In evaluating malocclusions in similarly deficient animals by the cephalometric technique, facial angles were not found to be equally affected, nor was retardation of different skeletal parts uniform. It is of interest to note that Deuschle and Warkany state, "Such results can be obtained only under strict experimental conditions in animals subjected to environmental regulations showing little resemblance to human living conditions."[12]

Riboflavin deficiency is characterized by corneal vascularity, photophobia, scaling dermatitis in the naso-labial folds and angular cheilosis. The tongue in early stages is not affected, but as the disease progresses to a more chronic state it becomes smooth, gelatinous and magenta in color. Although riboflavin deficiency is found very frequently in children, discussion of this disease will be limited to the adult, with particular emphasis on the edentulous patient.

Angular cheilosis is of paramount interest, especially in the edentulous patient, for it has been observed that this lesion is directly related to failure to restore normal vertical dimension and facial contours with artificial dentures after the teeth are lost, in addition to *being a manifestation of riboflavin deficiency. Infection at the angles is always secondary to one of these primary causes.*

Angular cheilosis starts as a pale, wet patch at the angle of the mouth, spreading laterally to form a triangular lesion. Although it can occur at any age, a more chronic lesion is usually noted without a macerated crust, with prominent scars at one or both angles in the adult edentulous patient. This can best be illustrated by the following case report:

Mrs. H. E. came to the Nutrition Clinic of the Hillman Hospital, Birmingham, Alabama, having complained of sore mouth and tongue for a period of 22 years. The angles of her mouth were cracked open and had become very sore, and the tongue and lips felt as if they had been scalded. Angular cheilosis was more prominent during the spring and summer and less prominent during the winter months, emphasizing the seasonal incidence of nutritional deficiency disease. The angles of her mouth and conjunctivae were red and inflamed and the tongue appeared red and slick. Evidence of old pellagrous dermatitis on the backs of her hands, legs and feet was noted. An analysis of the patient's dietary habits showed her diet to be grossly deficient in all essential nutrients, especially in B complex and protein. The patient could not masticate because of very poor, ill-fitting dentures (Fig. 2*A*), which she had been wearing since her teeth were extracted 25 years before. The patient received 5 mg. of riboflavin per day for a period of 5 months on two separate occasions. This relieved both the eye lesions and the cheilosis, *but at no time did complete improvement of angular cheilosis result.* The patient was then placed on 300 mg. of nicotinic acid per day for 2 months, which relieved the burning and scalding sensations of the tongue, but did not change the angular cheilosis.

In checking the patient's old dentures, a closure in vertical dimension of 11 mm. was noted (Fig. 2*A*). A new set of dentures was constructed (Fig. 2*B*) with normal vertical dimensions, adequate free-way space, and with facial contours restored by properly positioning the anterior teeth. This eliminated the wet skin fissures at the angles (Fig. 2*C*) and resulted in immediate improvement in the angles. Complete healing of the lesion (Fig. 2*D*) was effected after the patient had worn the dentures for 29 months.

The patient continued to improve in general health and well-being and no recurrence of the angular cheilosis was noted. It is interesting to note again that the patient's nutritional deficiency started when the teeth were lost and inadequately replaced. This further emphasizes the great responsibility resting on the prosthodontist's shoulders, for lost dental function must be restored by well-made, well-fitting artificial dentures.

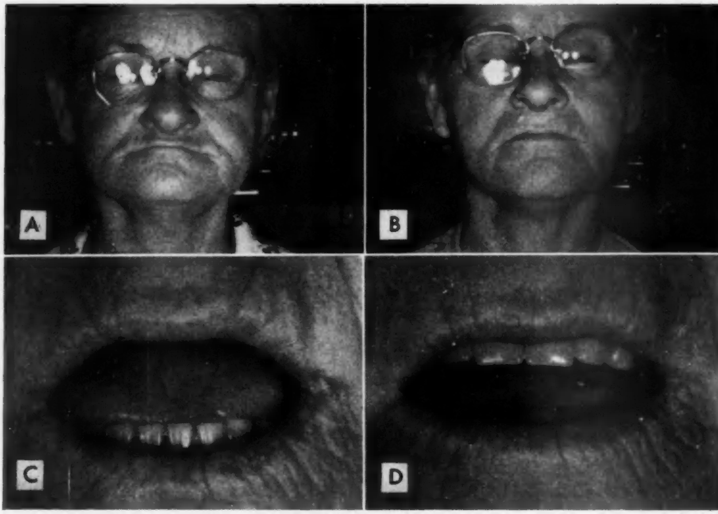

Fig. 2. *A*, Full face view of patient with old dentures in occlusion. Deep fissures are pronounced.

B, Full face view with new dentures in place. Note how normal facial contours are restored and skin fissures eliminated.

C, Patient with old dentures in place. Note incomplete healing of angular cheilosis even after exhaustive panvitamin therapy had been instituted. Angular cheilosis is still prominent at left angle.

D, Patient with new dentures in place. Angular cheilosis has completely disappeared 29 months after patient started to wear new dentures, although some response was noted immediately. The patient's diet and appetite have both improved tremendously. (Photos by author at Nutrition Clinic, Hillman Hospital, Birmingham, Alabama.)

Pantothenic Acid. Although the role of pantothenic acid in human nutrition has not been fully explained, it is interesting to note that Field et al.[13] and Brown[14] report that pantothenic acid may prove to be of value in treating cheilosis and glossitis resistant to other B complex fractions.

Thiamine. Vitamin B_1 (thiamine) has often been called the antineuritic factor because a deficiency of this vitamin causes profound peripheral neuritis. The author[15,16] and others have noted an increased sensitivity of the teeth, mucosa, and all oral tissues in thiamine deficiency. Edentulous patients frequently complain of pain over the ridge areas, even though no objective signs are present, and have great difficulty tolerating tissue-borne appliances, especially complete dentures.

Folic Acid. Folic acid is required by all cells, since it is essential for mucoprotein synthesis. Deficiency produces macrocytic anemias of

varied types. Orally, glossitis and stomatitis may be present similar to that noted with pellagra. Complete atrophy of the papillae of the tongue is noted in advanced states. Vilter et al.[17] described the response of macrocytic anemia patients to treatment while Spies et al.[18] and Ross[19] described the effect of folic acid on sprue.

Vitamin B_{12}. Another fraction of importance in macrocytic anemia is vitamin B_{12}. Vitamin B_{12} and folic acid are both intimately concerned with the formation of red blood cells. Severe deficiency produces pernicious anemia. It is important to note that the intrinsic factor in normal gastric juice must be present for effective absorption of vitamin B_{12}.

Glossitis is the most important oral manifestation of vitamin B_{12} deficiency, although painful lesions of the mucous membranes are noted in severe states in combination with degeneration of the spinal cord. These involve the buccal mucosa and the gingivae, and may involve the angles of the mouth. Stone et al.[20] noted a prompt response to administration of vitamin B_{12} in many cases where folic acid had been ineffective.

Other B Complex Vitamins. Inositol, biotin, choline, adenylic acid, para-aminobenzoic acid, strepogenin, vitamin P, rutin and other members of the vitamin B complex should be mentioned, although space limitations do not permit complete discussion.

Vitamin C (Ascorbic Acid). Deficiency of this vitamin is widespread because its daily requirement (75 mg.) is high, and because it is easily destroyed by oxidation. Vitamin C is necessary to form the intercellular substances (collagen and reticulum) cementing the cells together. Capillary fragility and hemorrhage (especially of the gums) is caused by failure of these cementing substances to confine the blood cells within the blood vessel walls. Faulty wound healing may result from prolonged deficiency. Vitamin C is interrelated with many other essential nutrients. It is involved in the formation of red blood cells and plays a part in the production of adrenal cortical hormones.

Clinically, the frank oral lesions of clinical scurvy (the specific disease caused by vitamin C deficiency) are confined to the *gingiva surrounding natural teeth* and are more prominent on the labial than on the lingual aspects and in the anterior region. Intensity of the mucosal symptoms of scurvy recedes posteriorly. The gingivae appear dark red, swollen, spongy and bleed easily as they are engorged with blood. In severe cases the teeth seem almost to be "buried" in the scorbutic gingivae. Oral filth and poor mouth hygiene frequently complicate the clinical picture, and it must again be emphasized that other deficiencies are always present even though the gingivitis appears to be predominantly scorbutic.

Minerals

Minerals are of great importance in human nutrition. The use of radioactive isotopes, however, is bringing minerals and mineral deficiency into prominence by demonstrating their importance. Calcium, phosphorus, and potassium are perhaps the most essential minerals, and when combined with oxygen, carbon, hydrogen, and nitrogen from air, water, and soil make up the bulk of the body weight. In addition, we must have sulfur, sodium, chlorine, magnesium, iron, manganese and iodine, in addition to an adequate supply of the trace minerals—copper, iron, fluorine, zinc, aluminum, silicon, boron, barium, strontium, lead, tin, cobalt, nickel, molybdenum, chromium and selenium. These elements are found in the form of salts, principally sulfates, nitrates, carbonates, phosphates, etc. Seafood provides an excellent source of trace minerals in the diet and should be prominently used in meal planning. Albrecht[21] points out that soils which are exhausted of their mineral content by wasteful farming methods produce foods with deficiencies of both protein and minerals, but with an excess of carbohydrates. He also states that calcium is the leader in marshalling other ions into plants from the soil, and as the calcium content rises, the protein and mineral content of food grown on these soils increases. Conversely, when calcium is leached out of the soil, potassium effectively makes bulk of forage which is predominantly carbohydrate but low in protein. Foods grown on low calcium soils, then, fail to provide adequate minerals and protein to develop and maintain healthy dental and periodontal structures.

DIETARY SUPPLEMENTS

Dietary supplements are of two types, synthetic and natural. Synthetic supplements are of life-saving value in cases of severe, frank deficiency disease, but should not ordinarily be used for routine supplementation; e.g., a patient suffering from scurvy should be given from 500 to 1000 mg. of ascorbic acid daily for a period of a week. At the end of this time all acute signs should have disappeared. Orange juice could not be given in quantities large enough to produce this result. On the other hand, natural supplements contain all the known and unknown essential nutrients and are of greater importance since they are used routinely when dietary deficiency exists. Wheat germ, brewer's yeast, natural B complex elixirs, etc., contain a wide variety of nutrients and all are extremely important. Treatment should always be directed, however, *to maintain the patient's metabolism on a good dietary rather than routinely depending upon supplements.*

Every case should be treated individually. The use of "shot-gun" preparations purported to contain all the vitamins and minerals should be discouraged, as they seldom contain a high enough dosage of any one fraction to do a complete job.

To summarize, a complete diagnosis should first be made and treatment planned with the following triple objective: (1) to eliminate severe fractional deficiencies with synthetic supplements in large doses over relatively short periods of time; (2) to assure optimal intake with natural supplements even though no physical evidence of deficiency disease is present: (3) *improving the patient's dietary* to include the daily requirement at the very minimum of *all* nutrients.

SUMMARY AND CONCLUSION

The edentulous patient must depend upon the prosthodontist to construct a well functioning set of complete dentures if he is to maintain optimal dietary intake and thereby insure continued good health.

The diet and nutrition of the edentulous patient profoundly affect the success or failure in the wearing of these dentures. Inadequate, deficient diets, as well as malfunctioning artificial dentures help to produce chronic nutritional deficiency disease which causes the patient to lose appetite, eat less, and eventually decline in health.

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430 East Las Olas Boulevard
Ft. Lauderdale, Florida

Criteria for the Use of Fixed Prosthesis

DAVID H. COELHO, D.D.S.

In this era of the recognition of full oral treatment, fixed prosthesis has become the method most desired by the majority of dentists in the replacement of missing teeth. It is agreed that, where possible, this is the method of choice. In the acceptance of this belief, it is essential that a full evaluation of all diagnostic data be made. The conclusions arrived at may indicate a treatment plan for a fixed appliance but, on the other hand, a contraindication may be seen. Again, a combination of fixed and removable restorations may be suggested, each of which will be of mutual aid to the other. It will be the purpose of this article to point up the diagnostic criteria essential to a successful fixed prosthesis. While detailed techniques concerning other phases of dentistry are not in the scope of this writing, it is well to remember that the mechanics of restorations cannot be separated from considerations of the periodontium, the use of oral surgery, orthodontic therapy, endodontics, basic operative procedures and the general considerations of histology and pathology.

In any corrective procedure, certain basic procedures are necessary from which one learns the requirements of his ultimate treatment. These are, simply, study casts of the mouth, a full series of roentgenograms, a clinical examination of the mouth and a patient history. Each gives specific information that cannot be obtained in any other way. When extensive construction seems indicated, an articulator mounting of the study casts is urgent.

PATIENT ATTITUDE

The first consideration is the type of patient and the history of that patient in previous dental experiences. Many people have a distaste for anything of a fixed nature in their mouth. This may be a result of a bad experience with this type of treatment or simply the result of a conversation with a friend. Unless this patient is re-educated concerning the value and serviceability of a fixed appliance, difficulty will be

had in the various procedures of construction. Explanation of what is to come, why it is done, and what can be the result will do much to create a desire for the work as well as to maintain harmonious relations between patient and dentist.

OCCLUSAL STATUS

The facial contours are related, in many instances, to the occlusion of the individual. While it is true that we see some patients whose facial appearance belies the normal occlusal relation and periodontic condition, we also see many whose appearance has been changed through loss of teeth. The dentist must then determine whether improvement of the facial contour is within his province. This will lead, naturally, to the consideration of changed vertical dimension and the reasons for the change. Loss of teeth and excessive occlusal wear are the most common causes (Figs. 1 and 2). Replacement of missing teeth with fixed appliances in four quadrants of the mouth will permit correction of vertical dimension in some instances. However, this vertical correction, if indicated, should never be attempted unilaterally. Excessive occlusal wear in young persons is usually indicative of vertical loss, whereas in older patients it is a physiologic process without loss, owing to the phenomenon of continual eruption. In the first type, a complete correction is indicated for the prevention of further reduction of vertical dimension, sensitivity, discomfort, and for cosmetic considerations. In the second type, the older patient, individual teeth may be treated, where indicated, restoring them to the occlusal plane as presented by the patient. If esthetics does not enter the picture, complete correction may be done without change in the vertical dimension. Sensitivity and discomfort are not usual complaints in the older patient.

As a general rule, where simple fixed prostheses are to be inserted, maintenance of or correction to the given occlusal plane is the indication. For example, an extruded tooth opposing an edentulous space should be reduced to the normal plane before construction of the fixed appliance. All extruded teeth must be considered areas of trauma, food impaction and possible causes for failure of a fixed appliance.

ORAL HYGIENE

Many words have been written concerning oral hygiene and its importance. The maintenance of any appliance, whether fixed or removable, is greatly dependent on the health and cleanliness of the

individual. It has often been advised that no fixed appliance should be constructed for a patient who shows oral neglect. Rather, the use of a removable type will permit this kind of patient more liberty. It is this writer's opinion that the foregoing premise is completely faulty. A neglectful patient will lay himself open to difficulty regardless of the type of appliance used. The same high level of care is required with

Fig. 1. Severe abrasion and loss of teeth resulting in decrease of occlusal vertical dimension and protrusion of mandible.

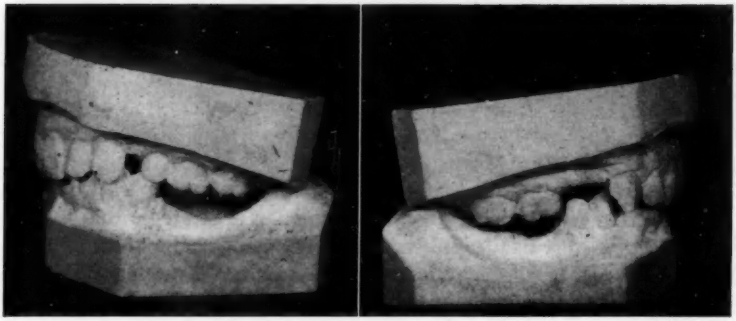

Fig. 2. Loss of posterior support resulting in decrease of occlusal vertical dimension and retrusion of the mandible.

both kinds of replacements. However, the complete coverage of abutment teeth is the best protection against caries in such mouths. When fixed constructions are to be used in conjunction with removable appliances, the crowning of the tooth which will act as the abutment for the partial denture is a necessary step to maintain the hygiene in that area. It may serve other purposes in addition; for example, in correcting the contour for proper clasping. The patient who exhibits good oral hygiene will have a much greater chance for long service of any type of restoration than the patient who is failing on this score.

SUSCEPTIBILITY TO CARIES

The susceptibility to caries is a most important diagnostic fact. Many years ago, when proximo-occlusal inlays were used extensively for bridge attachments, the remaining untouched proximal was even then looked upon as a possible weak link. Techniques changed to include that vulnerable area into the mesio-occlusal-distal inlay. But there were still conditions existing that did not satisfy the requirements in a mouth that was highly susceptible to decay. The great line of marginal area in such restorations still remained a problem. The next step was the onlay, thus bringing the susceptible margin into a comparatively 'immune" area, the buccal and lingual occlusal one-third of the posterior teeth. It thus became increasingly apparent that the more of the clinical crown that was protected, the less was the chance for the decay process to initiate. The placement of the margins into the gingival crevice, while not a permanent position owing to physiologic recession, was at least a preventive measure in covering all tooth surfaces where caries may start. Dentitions that show rampant caries must be considered carefully before instituting corrective or restorative procedures. The success or failure of the appliance may lie partially in the proper recognition and treatment of the existing caries picture.

The presence of one or more extremely carious teeth in the arch may involve some question as to their use. Before further treatment planning is attempted, the question must be eliminated. Complete excavation and "temporizing" with cement is the indicated procedure. If involvement of the pulp is found, endodontic therapy or extraction must be considered. When the tooth concerned is a strategic one for the construction of a fixed appliance, extraction may alter the treatment plan. Removal of all decay in the entire arch is the order, rather than only the excavation of those teeth that may become the abutments for the restoration. By the same token, to keep badly tilted teeth may not be advisable if they will interfere with the attainment of good retention or an acceptable occlusal plane. If one knows the possibilities before entering into a final plan, much difficulty can be avoided.

LENGTH OF SPAN

The question arises relative to the number of missing teeth that may be replaced with a fixed appliance. No truly hard and fast rule can be applied since no two cases are ever exactly alike. Only a generalization may be made. If we were to consider one facet of this problem, it would be the size of the edentulous space. Anteriorly, the four incisors would be considered a sound replacement, and posteriorly, two bi-

cuspids and one molar. While many other factors must be evaluated, a longer span than those named would usually contraindicate the use of a fixed appliance. Since a fixed prosthesis is completely tooth-borne and the ridge area affords no support whatsoever, extremely long span replacements tax the ability of the natural tooth abutments to withstand the excessive force that will be applied. The design of the pontic surface may help to minimize this stress but there is a limit to this reshaping beyond which efficiency and balance will be lost. The shorter the span the greater the chance of a successful appliance, all other diagnostic factors being equal.

ALVEOLAR SUPPORT

A vitally important consideration for a fixed restoration is the alveolar support of the abutment teeth. This is the structure that will

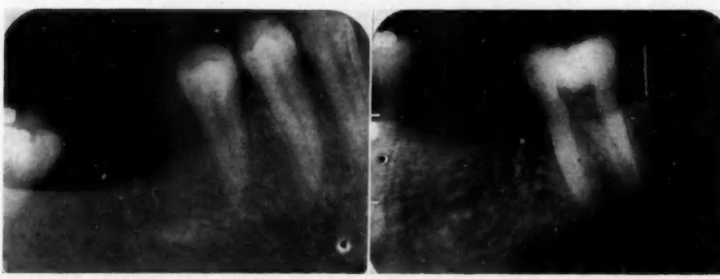

Fig. 3. Favorable alveolar support for a fixed prosthesis.

absorb the shock of mastication. Dense alveolar bone, showing good response to the stimulation of masticatory stress, is the most desirable type surrounding the roots of anticipated abutments (Fig. 3). Some mouths exhibit bone with large intercellular spaces, sometimes referred to as a cancellous type. The dentist must be wary of this kind of structure, making certain to obtain adequate support by inclusion of additional teeth and their supporting bone. This procedure, often referred to as "multiple abutments," will spread the strain over a greater area, lessening the impact on the individual abutment supports. Correct usage of this principle is a valuable adjunct in the proper planning of a fixed prosthesis. In those instances where some alveolar support has been lost, yet not enough to cause condemnation of the tooth and insufficient bone remains to permit the use of it as an abutment, the aid of an additional adjacent abutment will permit a serviceable fixed restoration to be constructed. In basic principle, bone is being added to bone for more foundation structure in order to resist

the force tending to loosen the abutment teeth. There are limits to the use of this technique. Teeth that show loss of bone structure in excess of one-half of the normal amount are not good prospects for maintenance. Supporting weakened teeth with additional castings on weak teeth does not offer a good prognosis. The best generalization would be to aid weakened teeth by including strong, well-supported ones as the extra abutments. Therapeutic splinting follows this same line of reasoning. Many teeth, previously condemned for periodontic failings, can be saved and helped to serve many more years of usefulness.

ROOT ANATOMY

Tying in with the type and amount of bone support is the evaluation of root length and root anatomy of the abutment teeth. It is a sound and logical thought that the longer a root, the better mechanical support it is, bone support being normal. A long cuspid root is definitely a better support than the normally short lateral incisor root. The rounded root of the central incisors does not offer the same resistance to displacement that the elliptical root of a cuspid does. Those teeth that have been treated by means of apicoectomy may fall into the category of short roots and must be treated as such. The short, thin root of the lower first bicuspids is well recognized to be a questionable support.

Those teeth that have two roots are firmer supporting structures than those with one. The tooth with three widely divergent roots is undoubtedly the best mechanical anchorage in the normal alveolar bone. Many second and third molars have fused roots, resulting in an extreme cone shape. These teeth must be carefully evaluated regarding the eventual stress to be placed upon them.

CROWN ANATOMY

A vital consideration is the length and shape of the clinical crown. This factor deals with the retention of the attachment casting upon the abutment tooth. The longer the crown the better the retention. A short-crowned tooth will not permit adequate length of grooves, as in a three-quarter crown, for sufficient retention. A full crown casting is a necessity on such short teeth.

The shapes of teeth vary from square to tapered, and this variation influences the use of the three-quarter crown preparation. When posterior teeth are involved and esthetics is not too great a consideration, the tapered type of tooth is not a great problem. However, when an anterior tooth or a first bicuspid is involved, the tapered tooth will

raise problems of both esthetics and retention. Because the length of the groove determines the retention factor, a tapered tooth will require extreme proximal slices to satisfy this requirement, but making such slices will violate the esthetic factor since much of the labial face will have to be removed. If esthetics is of great importance, as it usually is, the preparation used will have to be a variation of the full crown, e.g., an acrylic window. A similar problem exists when the tooth involved is a very thin one. The slices for a three-quarter crown are narrow labiolingually, resulting in short grooves. In addition to the lack of retention in such thin teeth is the darkening that takes place when the gold casting is inserted. The translucency of these teeth under normal circumstances is increased by the lingual reduction to

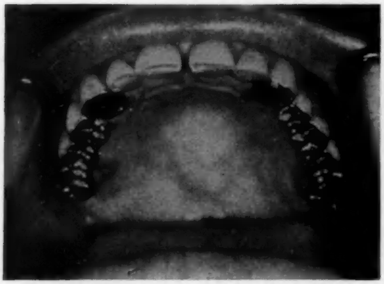

Fig. 4. Fixed appliances utilizing full cast crowns with acrylic facings.

allow for a thickness of gold. Again, therefore, the indication from both retentive and cosmetic standpoints is for the full crown with acrylic window or any variation of the full crown that provides satisfactory esthetics. (See Fig. 4.)

MECHANICAL FACTORS

Posterior appliances are usually on a straight line. Anterior appliances, however, are constructed on a segment of a circle (Fig. 5). Forces applied on such constructions are increased in varying amounts depending on the acuteness of the curve. The resistance forces, therefore, should be increased to counteract the additional stress. Usually the attachment selected will have the necessary retention form to keep it in place on the abutment tooth despite the inceased force applied; the damage will be done to the supporting structures of the abutment teeth. In order to resist this extra force, additional support must be obtained, and the amount of additional support will be dependent on the shape of the anterior arch form.

The more tapered arch demands the use of multiple abutments. The flat arch may not require more than the normal abutments, provided they meet all the basic requirements for teeth that are to be used as supports. If we consider an anterior replacement of two lateral and two central incisors, the simple mechanics of the replacement can be broken down into working arm, resistance arm and fulcrum. The working arm would be the distance from the mesial aspects of the abutment teeth to the midline of the two central incisors. The resistance arm would be the abutment teeth and the fulcrum would correspond to a straight line drawn between the mesial surfaces of the abutment teeth. In a flat arch form, well supported cuspids would be adequate. However, in

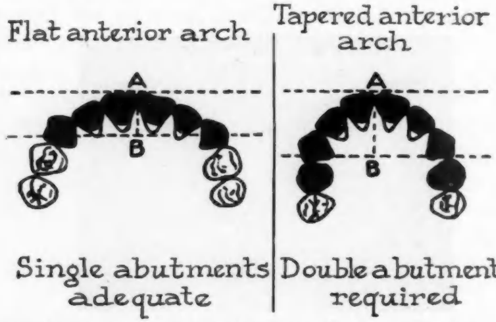

Fig. 5. Diagrammatic explanation of varying lengths of "lever arm."

a tapered arch, the working arm becomes much longer and additional resistance is obtained by using both first bicuspids and cuspids as the abutments. The resistance arm is thus increased. The principle of multiple abutments is the addition of more bone support to spread the force applied over a greater area. Individual retention of a casting on an abutment tooth is not increased with the use of multiple attachments. Only by the repreparation of a tooth, increasing retention form, will this be accomplished.

DEVITALIZED TEETH

The use of devitalized teeth as abutments is not contraindicated. In many instances, it is wiser to devitalize a tooth before the appliance is constructed. Badly broken down crowns affording little surface for proper retention can best be handled by instituting endodontic procedures, then rebuilding by means of a gold core or post and then completing the full crown preparation. All devitalized teeth to be used as abutments must have gold posts even though part of the natural crown remains. It is not advisable to include the post as part of the

crown which will act as an abutment. Paralleling of preparations is an essential step in constructing fixed appliances. The liberty of correcting the inclination of a root canal is far less than that permitted with a gold core. An attempt to seat an appliance in which the gold post is an integral part will often result in splitting the root of the abutment. The individual gold post's extension may be easily shaped to

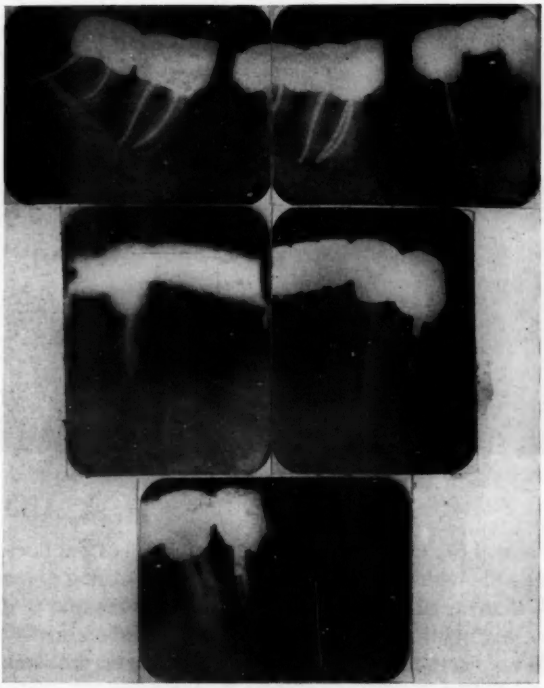

Fig. 6. Reconstruction of mandibular teeth using devitalized teeth.

parallel another natural abutment tooth. Devitalized teeth to be used as abutment teeth should be treated with gutta-percha fillings rather than silver wires. This will simplify the preparation of the canal to receive the post. (See Fig. 6.)

ESTHETIC FACTORS

Esthetics has become a major consideration in all dental restorative procedures. The display of gold is objectionable to most people. Originally, the use of a three-quarter crown was intended to eliminate the

display of gold necessary with a full crown. While this was accepted as an obvious improvement, a well made three-quarter crown must show a line of gold mesially, distally and incisally. The advent of plastics has permitted the use of full crowns without any display of metal. In many cases, retention requirements dictate the use of a full crown, and now no compromise with esthetics is necessary. Porcelain has long been in use and does afford the best cosmetic effects. The friability of the material, the disregard of sanitation and biologic requirements and the limitation in its use have long been disadvantages in the employment of this medium. The gold-plastic type of construction is far more desirable in maintaining the normal physiologic conditions and in providing the strength needed to avoid fracture. The

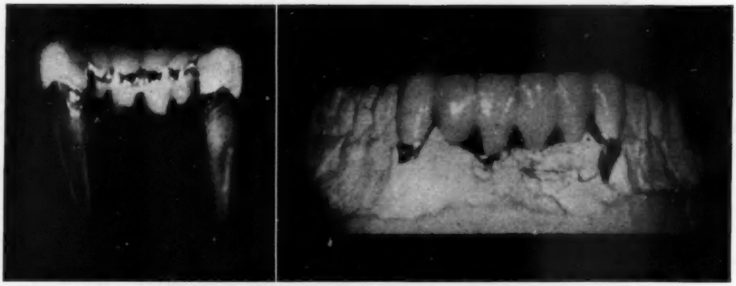

Fig. 7. Mandibular cuspid to cuspid replacement by means of porcelain fused to metal.

actual shade of the finished construction approaches but does not equal that obtainable with porcelain. Newer techniques using porcelain fused to metal, that permit proper placement of contacts and interproximal spacing along with excellent esthetics, increased strength and more leeway in application, will help to solve the esthetic problem to a great degree. (See Fig. 7.) This problem is distinctly one of the anterior region of the oral cavity and is of greatest importance in the anterior mandibular region. While the porcelain-metal technique is a great step forward, its use at the present time is best confined to those problem areas noted. The strongest construction still is the gold-plastic type and it should be used wherever possible to avoid future difficulties.

Plastics have the great drawback of losing shade and wearing away. The improvement of the material during the past five years has been tremendous and gratifying. Based upon the clinical evidence available, plastic-faced goldwork has done much to improve the status of fixed appliances. When properly executed, it is a most serviceable and esthetic construction.

APPLIANCE DESIGN

The design of a fixed appliance follows as the next consideration. This design has nothing to do with the types of attachments to be used; it is merely a decision concerning the number of pontics and the number of abutments that will satisfy the requirements of the case. Many of the factors previously discussed must play an important part in this decision. Let us start with a comparatively simple replacement and discuss the points involved in designing the case. The upper lateral incisor is missing. The cuspid is a long-rooted and well-supported tooth and the occlusal relation is well balanced. A cantilevered replacement

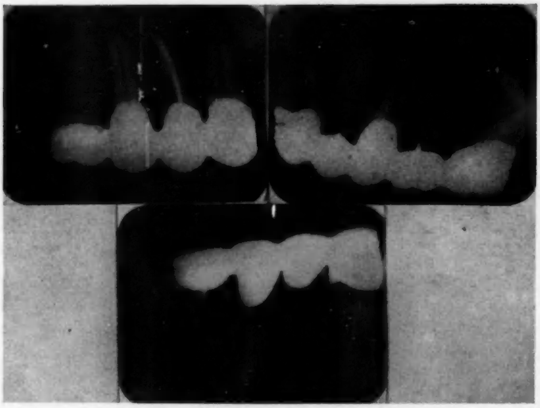

Fig. 8. Cantilevered replacements.

of the lateral from the cuspid would be an acceptable design. This, however, is the only situation in which a tooth may be cantilevered from an abutment. If the cuspid support were not ideal or the occlusion far from ideal balancing, under no circumstances should the design have any less than two abutments. Ideally, both the central and the cuspid should be used. Where esthetics may suggest that the natural central incisors remain untouched, a cantilevered design utilizing the cuspid and first bicuspid may be considered. This design of a freehanging pontic may be used in other areas of the mouth where the principle of multiple abutments can be employed if this type of design will help to simplify the construction and still offer a successful prognosis. For example, the replacement of a mandibular first molar when both the second and third molars are missing and an upper full denture is present is best accomplished by cantilevering the first molar, utilizing two or three abutments (Fig. 8). One must remember at all

times that this type of construction is not ideal and should be used only where it will meet a specific need. It should be noted that, in some instances, the patient feels a lack of security with this type of appliance (especially where opposed by natural teeth) and fails to exert any masticatory effort on that side. Whenever temporomandibular joint symptoms are present and bite corrections are indicated, it would be wise to avoid the use of cantilevered appliances.

As the design of the appliance becomes more complex, the use of the interrupted type is of great value. When a large span is broken by the presence of a single tooth in the center, it may be thought of as two separate appliances using a common abutment. If all considerations of bone support, root length and span length remain favorable, then single abutments at either end plus the one in the center of the span

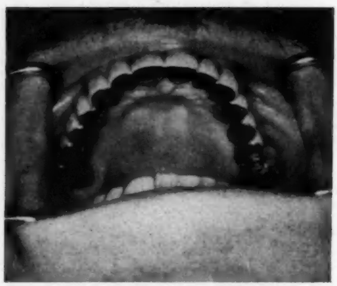

Fig. 9. Complete maxillary replacement utilizing one fixed prosthesis.

are adequate. Amplifying this thought, the interrupted type of span may vary from a two-pontic, three-attachment replacement to a fourteen-unit replacement with six attachments and eight pontics (Fig. 9). In the latter design, a border area between fixed replacements and removable replacements is reached. The dentist must consider very carefully all the factors involved, including possible future difficulties and their solution. A mouth that offers two premolars, two cuspids and two molars as abutments may lead the dentist to think of the use of one fixed appliance or several fixed appliances. If, however, one molar is questionable, a fixed appliance using it as a support would be contraindicated. Again, if the patient is concerned about an eventual difficulty causing loss of the appliance, the procedure should be avoided. It is in such situations that advantages of a fixed appliance may be combined with those of a removable appliance, each working to enhance the other. In the large replacement just under discussion, to design the anterior segment as a fixed unit and the posterior replacements as a removable unit would be a happy solution. The fixed unit

splints the abutment teeth so that a clasp or precision-type attachment does not load the tooth as much as if it stood alone. On the other hand, the tissue-bearing area of the removable appliance lessens the load that would be applied on the molar teeth if they were to act as the distal abutments for a completely fixed appliance.

In another respect, the combination of the two types simplifies the design of a removable partial prosthesis. When single teeth are missing in interrupted types of spans, such as two maxillary lateral incisors and both second premolars and all the molars, the lateral incisors replaced as individual fixed appliances would obviate the need for extensions from the partial denture base. Of course, the support obtained for the abutment teeth of the removable appliance would be an added feature.

Clinical experience has determined that only two types of attachments should be considered for fixed constructions, the three-quarter crown and the full cast crown or its variations. Clinical observation shows that very seldom is there fulfillment of the conditions that will permit use of the three-quarter crown safely or esthetically. The attachment of choice has become the full crown because it offers retention, protection, liberty of alignment and occlusal correction and cosmetic satisfaction. In all extensive restorations it is the only attachment that should be used; this conclusion is based on the maximal protection against caries afforded by the full crown.

* * * * *

The many criteria discussed are essential considerations in determining the success or failure of a fixed prosthesis. The one factor not yet named, but of maximal importance, is the judgment of the dentist in evaluating these criteria. Serious thought must be given to weighing the various factors in their proper light. Compromise may sometimes be necessary, but good individual judgment will keep compromises at a minimum. The result should be a fixed appliance that will be both functional and serviceable.

510 Madison Avenue
New York, New York

Occlusion in Relation to Prosthodontics

Vincent R. Trapozzano, D.D.S.

There can be no intelligent practice of dentistry without a knowledge of occlusion. Literally, occlusion is the cornerstone of the practice of dentistry. No phase of dentistry can be practiced without careful consideration being given to the resultant occlusion.

Much controversy exists as to what constitutes proper occlusion. The fact of controversy is not surprising; it may well be considered inevitable. Two individuals looking at the same set of facts can, and often do, come to radically divergent conclusions. Both may be right in the light of their own experience, ability, and power of observation, or the manifestation of the person being tested at the time the test is performed. Many of our present concepts concerning occlusion are difficult to prove or disprove. Scientific evidence is difficult to accumulate because of the problem of establishing satisfactory controls. What evidence is obtained is generally obtained by clinical evaluation. While this method of testing possesses a great deal of merit, its limitation lies in the fact that large numbers must be tested if the findings are to have any value. Evaluation of the information gained in mass testing must be carefully considered.

Knowledge of occlusion is based on the anatomy and physiology of the parts concerned. For any sufficiently large group examined, the anatomy of the parts concerned will not greatly differ. This is an accepted fact. What does differ greatly, even within a group of a relatively small number of persons, is the function of these anatomic parts. In addition, interpretation of observed phenomena will vary with different individuals concerned in conducting experimentation. Evaluation and clinical application of the data obtained are difficult. To consider one factor, muscle tone varies from time to time even in the same individual, and variation of muscle tone within groups of individuals mounts ad infinitum.

A change in muscle tone will inevitably result in a change in functional movement. Movement during a period of lessened muscle tone will not be the same as movement made during increased muscle tonus.

Yet, at the time the observations are made, the data obtained could be quite accurate *for the individual being examined.* As will be pointed out, because of change in muscle tone, centric relation records must be considered transitory.

Perhaps our main error lies in the fact that we are trying to fit all individuals into one generalized pattern of functional behavior. The pattern into which these persons are fitted will be the occlusal concept which we as individuals deem to be correct.

Recent publication of the Glossary of Prosthodontic Terms* has aided materially toward clarification of the proper use of terms and their meaning. All prosthetic terms used in this article will follow the definitions suggested in the Glossary.

CENTRIC RELATION

There is little doubt that the correct registration of centric relation constitutes one of the most important steps in prosthodontics. Without a proper centric relation registration, our work is doomed to failure. The continuing discussion of what constitutes a correct centric relation record merits some clarification.

Centric relation is defined as "the most retruded relation of the mandible to the maxillae, when the condyles are in the most posterior unstrained position in the glenoid fossae from which lateral movement can be made, at any given degree of jaw separation." It is of extreme importance to remember that the position of centric relation can be assumed by the patient by voluntary muscular contraction. No force or strain should be applied to the mandible while making this registration. It should also be kept in mind that when the mandible is in rest position, it *is not* in the most retruded relation to the glenoid fossae. Actually, in rest position the mandible is slightly anterior to the most retruded relation. Since in rest position the muscles attaching to the mandible are in a tonic state of equilibrium, the heads of the condyles may be considered as being in a neutral condylar position.

As previously pointed out,[1] a registration of centric relation made at any given time may be considered correct and so proven by any means or techniques at our command. However, unequal tonicity of the muscles attaching to the mandible may produce a registration which does not immediately reveal its inherent inaccuracy. Unequal and unstabilized muscular tonicity is quite prevalent. Many factors will have a tendency to produce an unequal pull on corresponding musculature on both sides of the mandible: chewing habits, disuse, atrophy, uneven wear of teeth if present, premature loss of teeth with-

* In J. Pros. Den., Vol. 6, March, 1956, following p. 286.

out replacement, etc. Situations of this type will be reflected in the fact that attaching muscles on one side of the mandible are not capable of exerting as much contractive power as the muscles on the other side of the mandible. It will follow, then, that the condyle on the side of the lessened muscular contraction will not be brought back quite as far as the condyle on the opposite side. Centric registrations made under these circumstances may be rechecked repeatedly, and the registration accepted as being correct, since there is no indication of the inherent muscular imbalance discernible in the registration. If this registration is utilized in the treatment of the patient, examination of the individual's occlusal relation, after a varying period of time, will reveal a disharmony of occlusal relation which may be directly attributed to the change in muscular balance. Clinically, any centric relation registration must be considered transitory and, therefore, subject to repeated checking to correct for any changes which may occur. It is only in this manner that progressive changes (increased tonicity) or retrogressive changes (decreased tonicity) may be compensated.

CENTRIC OCCLUSION

With natural dentition present, even in a person with a "normal" occlusion, it is extremely rare to find that centric occlusion coincides with centric relation. So long as this difference is within the limits of physiologic tolerance, no untoward effects will be manifested. However, should this occlusal disharmony exceed the physiologic limits of toleration, a breakdown of the tooth-supporting structures or the temporomandibular joint or both may be expected to occur.

It is difficult, if not impossible, to determine for any one individual the amount of difference between the positions of centric relation and centric occlusion that is within the limits of physiologic tolerance. Clinically, constant vigilance must be exercised in evaluation of clinical manifestations of possible breakdown of supporting structures in order to forestall injury.

In complete denture construction the course of our clinical procedures becomes clear. Centric occlusion and centric relation must be made to coincide. Selection of the centric relation position to serve as the starting point for the development of our occlusion is based on two main points:

1. Centric relation represents the extreme posterior unstrained position to which the heads of the condyles can be brought. Our endeavor will then be to construct and balance our occlusion from this point posteriorly to all positions anteriorly which the operator believes will be utilized by the individual concerned.

2. Centric relation, being a "terminal" or "border" position, can be constantly rechecked; for example, it is possible to reposition the mandible to the same degree of retrusion each time a registration is made. Obviously, any position anterior to this "most posterior unstrained position" of the condyles cannot be duplicated except by pure chance.

REST POSITION

Rest position is defined as "the position which the mandible assumes when the attaching muscles are in a relaxed state of tonic equilibrium." For purposes of mouth reconstruction and in complete denture construction, it is important to remember that the rest position should be noted when the patient is sitting upright, with the head so poised that the Frankfort plane lies in a horizontal position.

With the mandible in rest position, two factors must be considered: (1) the amount of free-way space (interocclusal clearance) which exists, and (2) the relation of the heads of the condyles in the glenoid fossae.

Thompson[2] pointed out that the rest position remains fairly constant throughout adult life. Within broad limits my own clinical observations indicate that the theory of constancy of the rest position is subject to modification. Changes do take place which may be accelerated by change of muscle tone, habit, and premature loss of teeth.

Thompson further pointed out, in his statistical study of the amount of free-way space, that the interocclusal clearance averaged 2 to 3 mm. In a more recent study the same author[3] stated that "the rest vertical dimension established by the mandible in its rest position is greater than the occlusal vertical dimension, and it is constant in most instances regardless of the status of the dentition. The difference in the two face heights should be approximately 2, 3, or 4 mm., and this is the average allowance for the free-way space or interocclusal clearance that exists between the maxillary and mandibular teeth when the mandible is in rest position." It should be understood that these figures are of statistical interest only. The selection and constant use of a 3 mm. free-way space would be incorrect. Many patients present with an interocclusal clearance of only 1 mm., and an interocclusal clearance of 6 to 8 mm. is not uncommon. Thus, the amount of interocclusal clearance which should be permitted any individual patient must not be based on average or approximate distances. This clearance must be determined in conjunction with other factors, such as degree of tooth wear if natural teeth are present, muscle tone, facial contour as viewed from a frontal and sagittal plane, and artificial tooth positioning (posteriors and anteriors). As suggested by Sears,[4] parallelism of the edentulous ridges when the casts are mounted on an

articulator serves as an excellent contributory guide in determining interocclusal clearance. The use of phonetics for determining vertical dimension has only highly limited value. To employ successfully the technique of phonetics in the determination of this relation in the edentulous patient, the following conditions must obtain:

1. The patient must have had previous denture experience. Learning to speak with complete dentures requires a varying degree of practice by the patient. To place trial dentures in the mouth of a patient with no previous denture experience and expect him to make the various phonetic sounds necessary for proper testing is beyond the realm of reasonableness, and seldom can be accomplished successfully.

2. The trial dentures must closely approximate the completed dentures as to peripheral width and extension, contour of flanges, and tooth position. An accurate estimate of interocclusal clearance cannot be made with the use of relatively clumsy occlusal rims. Not only will phonetics be interfered with, but also the act of swallowing if it is employed as part of the technique.

RELATION OF HEADS OF CONDYLES TO GLENOID FOSSAE

Next, let us consider the position of the heads of the condyles in the glenoid fossae when the mandible is in rest position. In this position the attaching muscles are in a relaxed state of tonic equilibrium, and the heads of the condyles are *suspended* in the glenoid fossae. The teeth, if present, are of course out of contact. In this *suspended* state the condyle heads are in a neutral condylar position. It is from this position that the mandible can, by voluntary muscular action, be moved upward, forward, distally, and laterally or in any combinations of these movements. It should be clearly understood that when the mandible is in rest position, the heads of the condyles *are not* in centric relation. As was pointed out, for the condyles to be in centric relation they must be in their "most retruded unstrained" position, a condition which obviously does not exist when the mandible is in rest position. It should be emphasized again that the "most retruded position" is the position of choice when undertaking the construction of complete dentures or in the reconstruction of occlusal relationships when teeth are present.

COMPARISON OF CENTRIC RELATION AND CENTRIC OCCLUSION

Centric occlusion is that occlusal position in which the teeth are making maximal contact while the heads of the condyles are in the "most retruded unstrained" position. Natural teeth are rarely in centric occlusion as defined, despite the fact that they are making maximal contact. Whether or not this is a "normal" situation is open to ques-

tion. The fact is that many persons with an apparently unmarred occlusion are capable of moving their jaws slightly to the distal to the position of centric relation from the position of maximum occlusal contact. The fact that no untoward effects result because of this difference in position from centric relation to maximal occlusal contact indicates that the change must be within the range of physiologic tolerance. However, should the condylar position, when the teeth are making maximal contact, become seriously altered owing to tooth wear, premature loss of teeth or faulty restorations, and should a perceptible malocclusion occur, untoward sequelae may be expected. As a result of malocclusion the supporting structures of the remaining teeth may break down or injury may occur to the temporomandibular joint, or both. The criteria to be used in determining the amount of difference between the positions of centric relation and maximal occlusal contact which is physiologically acceptable are conjectural. It is probable that useful criteria cannot be established because of great variation in individual reaction to stimuli.

It is significant, however, that the treatment of a malocclusion of natural teeth is accomplished by having the patient close in *centric relation*, and then noting the points of premature contact. This is a logical procedure. As was pointed out, the patient can cause the condyles to be brought into their "most retruded position" by voluntary muscular contraction. Occlusal correction, therefore, must start from this position, since only thus can the malocclusion present be eliminated within the entire range of possible occlusal contact.

The reasoning used for the selection of the "most retruded unstrained position" (centric relation) as the starting point for the correction of malocclusion, denture construction, and occlusal reconstruction is best explained by considering an arrow-point tracing. Not infrequently, when making an arrow-point tracing, the initial tracing will be found to be somewhat rounded or blunted. This signifies that the heads of the condyles are not yet in their "most retruded unstrained position"; that is, the patient has not placed the mandible in centric relation. Such a rounded apex may be the result of technical error, such as unstable baseplates, striking of baseplates or occlusal rims during eccentric movement, or tilting of the opposing base because of failure of the central bearing point to maintain proper separation of the bases. Or, the rounded apex may be due to an inability of the patient to understand and execute the movements required for the production of a proper tracing. Habit may play a part.

However, if possible technical interferences are removed and the patient is made to understand what is required, it will be found that a sharply defined apex will be produced.

If, as has been advocated by some, the blunted or rounded apex had been accepted as the position of centric relation, failure would be inevitable. With the blunted apex (which represents a position anterior to centric relation) used as a starting point for denture construction, mouth rehabilitation, or correction of occlusal disharmony, it would follow that whenever the patient decided of his own volition to close into the more retruded position (apex of the tracing), a definite malocclusion would occur. The acceptance of the blunted apex for a starting point in occlusal reconstruction would invite a temporomandibular disturbance, while if the blunted apex were used in complete denture construction, shifting and sliding of the denture bases would occur and result in an instability of the denture and associated undesirable sequelae.

It is recognized that patients will make many initial contacts in some position other than that of centric relation. For example, it is commonly assumed that during the act of swallowing, the mandible is always drawn back to the position of centric relation. This is not true. Swallowing frequently takes place with the teeth in some position anterior to centric relation. It becomes important, then, that we avoid "grooving" the patient to the most retruded position before inclined plane contact is made. This is accomplished by allowing for "free play." Provision is made for "free play" by slight widening of the central grooves or fossae of the posterior teeth, thus providing an area larger than the size of the opposing cusp which fits into the groove or fossa when initial tooth contact is made. The "free play" thus allows for a limited range of horizontal movement of the mandible without engaging the inclined planes of the teeth.

THE MASTICATORY CYCLE

All movement is functional. Movement may be described as masticatory, non-masticatory, reflex, gliding, etc. It is incorrect to speak of mandibular movement as non-functional. When there is movement there is function, regardless of the nature of the movement.

Mandibular movements during speech and mastication are varied and complex. The mandibular joint (ginglymoid-arthrodial) is a sliding hinge joint. Because of its flexibility, it has often been called a universal joint. This is, of course, incorrect. Because of the great degree of adaptability of the joint and the highly variable limits of physiologic tolerance of different individuals, much misunderstanding has resulted. The existence of a wide range of physiologic tolerance does not imply that the movement of the joint is vague and free swinging. The opposite is true. The envelope of movement made within the boundaries

of any selected range of movement is quite constant. Deviations therefrom are the result of possible tissue displacements. However, these displacements must fall within the limits of physiologic tolerance if the joint is to remain healthy. It must be kept in mind that, while the movements are not as constant as those made by two machined parts, they are as constant as any relationship which can exist between healthy, living tissues.

Any analysis of the chewing cycle must be made by noting the movement in a three-dimensional relationship: frontal, horizontal, and sagittal.

Repeated tracings on a frontal plane indicate that the movement is essentially one of opening, followed by a side shift laterally, and finally an upward and inward movement. In a sagittal plane the movement consists, in general, of a slight protrusion, associated with the eccentric positioning of the mandible on opening, and then an upward and backward movement. Completion of the masticatory stroke is generally toward centric relation. Movement on a horizontal plane will follow the pattern generated as in an arrow-point tracing.

Masticatory movement on a frontal plane has often been described as being teardrop in form, and all too frequently this term has been adopted to describe this movement. Recent investigation and study has convinced me that the movement scribed *may be* teardrop in shape, but that in many instances it will not bear the slightest resemblance to a teardrop. Recent experiments in registering this movement on patients chewing roasted peanuts and carrots reveals that the upward and inward stroke, as it approaches the terminal position of tooth contact (toward centric relation), frequently scribes an angle which in many instances is close to 60 to 80 degrees. Not infrequently, while some portion of the bolus remains between the teeth, the angle of approach is from a position superior to the final point of contact. It may be noted that if the subject is chewing a bolus of food on the right side, he will frequently scribe an arc on the side opposite to that which is being generated by right-side chewing. In the former instance it may be assumed that either (1) the patient has exceeded the width of the food table provided by the posterior teeth or (2) he is attempting to reposition the bolus in order to continue mastication. In the latter instance the path generated on the opposite side may be due to an attempt on the part of the patient to reposition the bolus.

THE HINGE AXIS

The presence of a hinge axis of the mandible within a wide range of movement from overopen to overclosed has been demonstrated repeat-

edly. Unless there occurs an appreciable amount of change in muscle tonicity, the point of hinge axis registration can be relocated from time to time well within the bounds of practicability. The fact that the registration of a hinge axis involves a "learned" movement in no way invalidates its accuracy. It must be understood that the hinge axis registration is a "terminal" or "border" position. As with centric relation, it is precisely because the hinge axis represents the "terminal" or "border" position that it is capable of being recorded repeatedly with a high degree of accuracy. The importance of this registration is based on the conviction that the registration of the condylar paths, which include Bennett movement (the side shift of the heads of the condyles in the glenoid fossae), should be made from the hinge position which forms the starting point for eccentric movements. Accurate transfer of these records to an articulator which is capable of reproducing these positions and paths of movements is desirable in order to produce harmonious movement. This is especially true when undertaking occlusal reconstruction. Its practical value in the construction of complete dentures has not been demonstrated.

Much controversy exists as to whether or not closure from the rest position to the occlusal position is a hinge axis movement. Much of the disagreement results from failure to distinguish between the directions of movement which the individual can make when closing from rest position to occlusal position. When a closing movement is made, the general direction and range of closure may vary greatly. Movement may be lackadaisical, in which case closure may take place with the condyles at some distance from the most retruded unstrained position. Registration of this type of closure would frequently indicate that the patient was not making a simple hinge axis closure, but rather a closure which included translatory movement. If, however, the patient were to initiate voluntary muscular contraction sufficient to bring the condyles into their most retruded unstrained position during the closing movement, the result would, without question, be a hinge axis movement. It follows then that closure from rest position to occlusal position may, and frequently does, involve rotary or translatory movements or combinations of both.

RELATIVE IMMUTABILITY OF CONDYLAR MOVEMENTS

As has been indicated, the mandible is capable of an infinite number of movements which are either rotary, translatory or combinations of rotation and translation. These movements can be made at varying degrees of jaw separation, and in the edentulous patient they are controlled by the temporomandibular joint. The paths

to be followed by the condyles will in the main be controlled by (1) the bony limitations which comprise the joint, (2) the direction of pull and the tonicity of the attaching muscles, and (3) the limitation of movement dictated by the attaching ligaments. In the construction of dentures, these factors cannot be ignored. When natural teeth are present, the leading role in the dictation of the condylar path is assumed by the teeth. Evidence to establish the relative immutability of the path of movement of the condyles in the temporomandibular joint is based on the frequent clinical observation of the temporomandibular joint disturbances which can readily be ascribed to the presence of a malocclusion. The breakdown of the joints may be ascribed to their constant malpositioning beyond the range of physiologic tolerance caused by the lack of cuspal harmony with mandibular movement each time tooth contact is made. It is also apparent that in the presence of a malocclusion it is not always the joint which carries the brunt of injury. Frequently the havoc is manifested by a breakdown of the tooth-supporting structures, which gives further evidence that the mandible follows a relatively inflexible path of movement. If the temporomandibular joint enjoyed the latitude of free movement which is sometimes ascribed to it, then there would be no such pathologic entity as a temporomandibular joint disturbance directly traceable to malocclusion, and very few teeth would be lost because of traumatic occlusion.

OCCLUSAL CONCEPTS

Occlusal concepts fall into three general categories: (1) balanced occlusion, (2) spherical occlusion, and (3) non-balanced occlusion. Spherical occlusion can be classified as non-balanced occlusion. Generally speaking, the fundamental differences in concepts of occlusion will vary with the individual interpretation of mandibular movement. Two individuals viewing the same phenomena will not necessarily ascribe the same cause for the action which takes place. Techniques intended to utilize basic concepts will vary in degree in regard to the actual accomplishment of the end result which is being sought.

The concept of a non-balanced occlusion is predicated on the assumptions (1) that patients do not make eccentric movement during the mastication of food, and (2) that tooth contact rarely, if ever, occurs during the mastication of food.

As regards the lack of eccentric movement during the mastication of food, the preponderance of evidence points to the fact that eccen-

tric movement does occur. Hildebrand,[5] in his studies, found that tooth-to-tooth contact from the position of eccentric contact to centric occlusion averages between 1 and 2 mm. at the incisor point. Thus, movement in the region of the first premolar is approximately 0.66 mm. for every 1 mm. of incisor point eccentric movement. To insure freedom for potentially larger ranges of movement, cuspal harmony must be provided for from possible cusp-to-cusp contact in the eccentric position to and through the termination of the movement in centric relation.

Human beings, being possessed of great adaptability, can no doubt in many instances be *trained* to use a simple opening and closing movement during mastication. That patients can be conditioned to perform this type of movement continually has been demonstrated. The desirability of restricting the patient to a single type of motion can be questioned. To my knowledge no tests have been conducted to determine whether the food bolus can be broken down sufficiently for proper digestion when the patient is limited to a simple opening and closing movement.

The question whether or not tooth contact is made during the mastication of food has been the cause of much controversy. Prime succinctly stated the point with his statement, "Enter bolus, exit balance." From this it is to be assumed that balanced occlusion is unnecessary. This statement has not, to date, been supported by sufficient acceptable scientific evidence.

Whether or not tooth contact will occur during the mastication of food will depend upon (1) the vigor with which the patient chews the food, (2) the occlusal pattern of the tooth used; the sharpness of the cutting edges will materially influence the ease with which the food bolus is penetrated; and (3) the type of food being chewed and the size of the bolus.

Too large a bolus of food will not permit the patient to center the food properly over the food table for adequate mastication. Since all foods do not present uniform resistance, it is obvious that some foods will be penetrated with no difficulty, while other foods are so resistant that penetration cannot be expected to occur. More resistant foods must be macerated by the teeth in relatively slow stages until the food is reduced to a fine mixture. During these final stages tooth contact will be made.

The factor of relative tooth sharpness plays an important role in the maceration of food. Increasing the number of sluiceways and their depth, providing a narrow buccolingual tooth width, and the further lessening of occlusal resistance by the elimination of a posterior tooth or by increasing the spacing between these teeth are

some of the various means employed to diminish occlusal stresses and increase the ease of food penetration.

The vigor with which the patient masticates will affect the possibility of tooth contact. Chewing habits, insofar as they affect the length of time which the patient takes for the mastication of food, are an additional factor to be considered. Many patients gulp their food, while others carefully macerate each morsel before swallowing. In the latter instance tooth contacts will be inevitable.

The concept of balanced occlusion was well stated by Stansbery[6]: "Balanced occlusion involves a definite arrangement of tooth contacts in harmony with mandibular movement." Acceptance of this concept is based on the acknowledgment of three main factors: (1) the relative immutability of condylar movement, (2) the fact that eccentric mandibular movement occurs during function, and (3) the possibility of arranging tooth contacts in harmony with the resultant mandibular movements. Thus, the resultant occlusion will represent an attempt to construct an occlusion which will fit the pattern of movement of the patient being treated. It is a concept which permits the occlusion to be fitted to the patient instead of adjusting the patient to the occlusion.

The factor of relative immutability of condylar movements has already been discussed. Consideration of tracings made on a frontal plane during the mastication of a bolus of food indicates that lateral movement takes place. The possibility of arranging tooth contacts in harmony with condylar movement made by an edentulous patient depends upon three factors: (1) the condylar inclination (or path), (2) the incisal guide angle, and (3) the cusp angle. Of these factors, the first and second may be considered the end controlling factors. As has been indicated, *the dentist has no control over the condylar inclination.* It is the main controlling factor with which the patient presents himself. The incisal guide angle is largely determined by the operator, within the limits of ridge fullness and the tooth position which will permit an esthetically acceptable end result. This angle is formed by the amount of vertical and horizontal overlap. Within the limits stated, the operator may increase or decrease the incisal guide angle by changing the vertical and horizontal overlap. The mandible will follow any degree of incisal guide angle selected, and will do so without change in its own path of movement. Thus, to obtain harmony of cuspal inclination with these two end factors, it is necessary to set the posterior teeth at an angle which will satisfy these requirements. Only one cuspal angulation will accomplish this end result. For example, if the patient presents with a condylar inclination of plus 20 degrees on the right side and plus 15 degrees on the left

side and the incisal guide angle is set at plus 10 degrees, then the following cuspal angulations will be required: Assuming that the first molar is located at approximately one-half the distance between the condylar inclination (angle) and the incisal guide angle, then the cuspal angulation necessary for balance on the right side will be one-half the sum of 20 degrees plus 10 degrees, or 15 degrees, while on the left side it will be one-half the sum of 15 degrees plus 10 degrees, or 12½ degrees. In this situation cuspal angulation will increase progressively for the second molars, while it will decrease progressively for the first and second premolars on both the right and left sides.

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3900 Central Avenue
St. Petersburg 7, Florida

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